THE EOCENE TERTIARY OF TEXAS EAST OF THE BRAZOS RIVER.

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Since the publication of Dr. Hilgard's report on the Geology of Mississippi probably no other publication occupies so prominent a place among the geological literature of the tertiary deposits of the Gulf coastal slope as the "Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers," by Smith and Johnson.[1] The Tertiary section there shown has been recognized not only as the section of the Alabama beds, but has also been considered as typical of the whole tertiary areas along the Gulf coast. Dall says that the Gulf section has been practically determined and its fauna largely recorded in this section, but he considers that important information and a rich fauna may be obtained from the Texas section,[2] and lately, Harris, in speaking of the same Bulletin, says: "It was not until 1886 that the typical section of American marine Eocene, namely, that of Alabama was published.[3]"

At that time (1888) very little was known regarding the Texas Tertiary. Desultory work, it is true, had been done by several observers, and some fossils figured and described by Gabb and others, but no continuous or connected work had been attempted, or, if so, the results were inaccessible and unknown. It was generally conceded, however, that it might be safely assumed from the geological conformation of the neighboring States that all or nearly all of the divisions ranging from the Eo-Lignitic to the Grand Gulf, inclusive, were represented, and that a considerable part belonged to the Lower Eocene as seen at Claiborne, Alabama, and in Clark County, west of Claiborne.[4]

In 1889 the first systematic work in those deposits was begun by Prof. R. A. F. Penrose, Jr. During that year he followed three of the

[1] Bulletin 43 U. S. G. S., by Dr. E. A. Smith and Lawrence C. Johnson.
[2] Tenth Annual Report U. S. G. S., 1888–89, p. 168.
[3] Am. Journ. of Sci., Vol. XLVII, April, 1894, p. 302.
[4] Heilprin, Cont. to Tert. Geol. of U. S., 1884, pp. 37, 38.

great rivers: Brazos, Colorado, and Rio Grande, flowing across the Tertiary areas of the State, and the results of his examination have been published in the First Annual Report of the present Geological Survey.[5] Since that time the work of examining these beds has been carried on continuously throughout the eastern portion of the State almost altogether by myself, and the detailed results of these examinations, chiefly from a stratigraphic standpoint, have been published from time to time in the various Annual Reports of the Survey.[6]

During the course of these examinations Prof. Penrose's river section along the Brazos was re-examined, the section seen along the Trinity River, and another extended section between the Trinity and Sabine made, and extensive areas throughout other portions of East Texas, were examined in detail.[7]

While a great portion of the stratigraphy had thus been worked out it has only been within the last year that any of the immense collections of fossils obtained during the course of the work have been critically examined and described.[8]

While the prediction of Dall as to the richness of the fauna of the Texas section has been fully verified, various other conditions have come to light which, while they largely verify the Alabama section, at the same time add strength to the all-important fact that the geological conformation of neighboring States cannot always be relied upon as a guide to the geology of any portion of the southern or Gulf Tertiary.

A comparison of the two sections—Alabama and Texas—shows several material differences between which, prior to the work of the present Geological Survey, were never suspected to exist. The three sections of the Eocene, viz.: Alabama, Mr. Harris' section, and the Texas section as made by the State Survey, are here given for comparison.

[5] Preliminary Report on the Geol. of the Gulf Tertiary of Texas, by R. A. F. Penrose, Jr., First Annual Report Geol. Survey of Texas, pp. 6–64.

[6] Second, Third and Fourth Annual Reports Geol. Survey of Texas.

[7] Third Annual Report Geol. Survey of Texas, pp. 43–124; Fourth Annual Report Geol. Survey of Texas, pp. 43–53 and 67–76.

[8] For this work see Monograph of Texas Tertiary Fossils, by Gilbert D. Harris.

Alabama section:[9]—

			Feet.
Tertiary Eocene	Upper—White Limestone	Coral Limestone, Vicksburg?	150
		Vicksburg (Orbitoidal)	140
		Jackson	60
	Middle—Claiborne		140–145
	Middle—Buhrstone		300
	Lower—Lignitic	Hatchetigbee	175
		Woods Bluff	80–85
		Bells Landing	140
		Nanafalia	200
		Mathews Landing, Naheola	130–150
		Black Bluff	100
		Midway	25

In the American Journal of Science Mr. Harris presents a general section of the Eocene series of the Southern States. This is based to a considerable extent on the Alabama section, but modified to include and harmonize with his own observations.[10] This section is:—

Series Eocene	Stages.	Sub-stages.	
	Vicksburg	Coral Limestone	
		Vicksburg Beds	
		Red Bluff Beds	
	Jackson	Moody's Branch Beds	
		Mark's Mills Red Beds	
	Claiborne	White Bluff Marls (Mk)	
		Claiborne sand	
	Lower Claiborne	Ostrea sellæformis Beds	
		Lisbon Beds	
		Buhrstone	
	Lignitic	Hatchetigbee Beds	
		Wood's Bluff Beds	
		Bell's Landing	Bell's Landing Beds
			Gregg's Landing Beds
			Nanafalia Beds
	Midway	Mathew's Landing Marl	
		Black Bluff Clays	
		Midway Clay and Limestone	

The work of the Texas survey shows the Eocene Tertiary of that portion of the State lying east of the Brazos River to have a section of:—

[9] Bulletin 43, U. S. G. S., by E. A. Smith and L. C. Johnson, p. 18.
[10] Harris, Am. J. of Sc., Vol. XLVII, April, 1894, p. 304.

	Stages.	Sub-stages.	Thickness. Feet.
Series Eocene	Lower Claiborne	Frio Clays	160
		Fayette Sands	400
		Yegua Clays	1,000
		Marine Beds	650
	Lignitic	Queen City Beds	60–70
		Lignitic Beds	1,000
	Midway	Basal or Wills Point Clays	260

The above section includes the whole of the Eocene deposits recognized in east Texas. As noted by Dr. Loughridge[11] the white limestones of the Claiborne are absent and neither the Vicksburg nor Jackson stages have been recognized, either paleontologically or stratigraphically, although both of these are reported as occurring a few miles to the eastward in Louisiana. The celebrated Claiborne sands are also absent.

No strata that might lithologically be referred to the *Ostrea sellæformis* beds have been recognized. *O. sellæformis* var. *divaricata* Lea, occurs in considerable numbers throughout the upper division of the Marine beds, and although increasing in number as this fossil ascends the scale, it can nowhere be said to be more characteristic of any of the beds than many of the other species found in association with it. This form of *Ostrea* has a vertical range of a little over two hundred feet.

It may also be said that no deposits corresponding to the Buhrstone of the Alabama section have been recognized anywhere throughout East Texas. The only deposits that might possibly be referred to this stage are the Queen City beds of red and white sands and clays, and even these, although filling the position occupied by the Buhrstone, do not correspond to any member of that stage lithologically, and besides, they are altogether unfossiliferous.

The lignitic formation, as recognized in the Texas sections, contains no such divisions as those characterizing the Alabama lignitic. From its base to contact with the overlying marine beds the Texas lignitic is made up entirely of sands, clays and lignites, and with the exception of a few broken plant remains the extended investigations of the Geological Survey have disclosed neither fossils nor green sands. It may be said to be altogether unfossiliferous.

[11] Cotton Production of Southern States, Tenth Census, Vol. V, Part II.

Into the general section, however, three divisons of the Lisbon stage have to be introduced, all of which, so far as at present known, are peculiar to Texas. There are (a) Frio Clays, (b) Fayette Sands, and (c) Yegua Clays. These overlie the marine beds in the reverse of the order here given and together aggregate a thickness of nearly 1,500 feet in East Texas, while farther west this may be considerably exceeded.

Frio Clays.

These clays form the uppermost division of the Eocene Tertiary as shown in the Texas section. They comprise a series of dark-blue, red, green, brown, and yellow clays when wet. They weather to pale blue, light red, watery green, gray, and pale yellow upon exposure and drying. In many places they carry numerous calcareous nodules, hard when freshly exposed, but in contact with the air they soon become soft and powdery, coating the exposures of the banks and outcrops with a fine, limy powder, and the clays themselves may be regarded as more or less gypseous throughout. In structure these deposits are sometimes laminated or partially stratified, but throughout their greater extent are massive and heavy bedded. The East Texas deposits appear to be unfossiliferous, but a considerable extinct fauna is reported from the beds lying in the central and western portions of the State.

Although reported as forming extensive deposits and covering a wide area throughout the region west of the Brazos[12] these clays thin out and are so covered by the overlapping Neocene deposits to the east of that river that their existence has only been noted at a few places. East of the Brazos these clays were first observed a short distance east of the town of Corrigan, in Polk County, where the section shows them to be dark-blue gypseous clays[13] and to lie between two beds of sandstone. Thirteen miles farther east, near Fleming,[14] an extensive outcrop of the same clays appears. Here, however, they present their calcareous features and appear to be devoid of selenite and are about 160 feet in thickness. Small outcrops appear at intervals along the Trinity and Sabine Railway and at Summit, in Tyler County, a section of a cutting on the Southern Pacific Railway shows the Frio clays to be about eighty feet in thickness and to be

[12] Third Annual Report Geol. Survey of Texas, p. 116.
[13] Third Annual Report Geol. Survey of Texas, pp. 62–63, and 117–118.
[14] Dumble, Journal of Geology, Sept., 1894, p. 554.

overlaid directly by the brown and gray sands of the latest Tertiary. The following section combined from two cuttings at Summit Station shows the relations of the Frio clays to the overlying and underlying deposits.[15]

Orange Sand or Lafayette.	1.	Gray sand with silicious pebbles	18 feet.
	2.	Conglomerate of silicious pebbles connected by a ferruginous matrix adhering to brown ferruginous sandstone, found in boulder form and in connection with an irregularly deposited stratum of ferruginous material changing gradually toward the north end of the cutting to a brown or pale red crossbedded sand interlaminated in places with lenticular shaped deposits of brownish-blue or pink clay . . . . . 10 to 13 feet.	
Frio Clays.	3.	Mottled-blue and brown sand clay	20 "
	4.	Pale watery-green sandy clay	20 "
	5.	Brown sandy clay	25 "
	6.	Pale blue sand and clay	15 "
	7.	Dark blue clay with limy concretions and gypsum crystals in places	20 "
Fayette Sands.	8.	Drab sandy clay becoming gradually the same as No. 8	30 "
	9.	Gray sandstones, coarse grained on top but changing to a fine grained blue stone at base . . .	120 "

Nos. 3 to 7 belong to the Frio clays.

Many deposits of these clays occur in Jasper and Newton Counties and extend almost to the Louisiana line.

West of Corrigan, deposits of the same character, occupying a similar position and of the same age, occur in the neighborhood of Longstreet, Montgomery County, and lately in an examination of the section at Riverside quarries, on the Trinity, Mr. Dumble found the same clays between two sets of sandstone and occupying the same position as the deposit at Corrigan.

While these deposits are only visible at intervals, often many miles apart, their generally uniform appearance, constitution and relatively coinciding positions between the overlying sands and cal-

[15] Third Annual Report Geol. Survey of Texas, p. 120.

careous clayey sands of the Neocene beds and the underlying Fayette sands appear to justify the inference that they form a continuous belt of deposits, somewhat irregular in width and thickness, from west to east and have a general tendency to decrease in areal extent and thickness as we go east.

Fayette Sands.

The gray sandstones as described by Buckley and Loughridge admit of a threefold division and possibly a fourth may be added upon farther examination and investigation, each being represented by beds differing widely from each other, both in lithological structure and faunal character. The uppermost division comprises a series of highly calcareous sands, sandstones and clays containing many water-worn cretaceous shells throughout the sandy portions, but carrying no indigenous invertebrate fauna.[16] Fossil bones have occasionally been reported from these beds and some have been described by Leidy[17] from Washington County and farther west. This division, however, belongs to the Neocene Tertiary. The middle portion, or Frio clays, have already been described, and the Fayette sands proper form the basal portion and probably include the hard silicious sandstones mentioned by Buckley.

The prevailing characteristics of these Fayette sands, as here restricted, are gray sandstones, white and gray clays, and gray sands. The sandstones are irregularly deposited and lie in beds from a few inches to ten, fifteen or twenty feet in thickness. In Jasper County, on the eastern side of the State, these sandstones range from four to ten feet in thickness and at Rockland, in Tyler County, the section shows:[18]

1.	Gray sand	4 feet.
2.	Coarse grained, gray sandstone	5 "
3.	Hard blue sandstone	15 "

Along McManus' Creek, near Stryker, in Polk County, these sandstones form an escarpment for nearly a mile in length and present a solid face of over ten feet, and at Hitchcock's quarry, about a

[16] Fourth Annual Report Geol. Survey of Texas, 1893, pp. 9–14 as Navasota Beds.

[17] U. S. G. Survey of the Territories, Vol. I. Extinct Vertebrata, by J. Leidy, p. 246 et seq.

[18] Third Annual Report Geol. Survey of Texas, 1891, p. 120.

mile north of Corrigan, the sandstones exposed show a thickness of over sixteen feet. Coming westward the thickness becomes less, as near Lovelady, in Houston County, the bedding is from ten inches to two feet. In Grime County the thickness has still farther diminished to from six to eighteen inches. Crossing the Navasota River the bedding begins to thicken to the westward, as a section near Wellborn Station shows them to have a thickness of two to six feet.

In texture these sandstones vary from a soft, indurated sand of scarcely sufficient cohesion to be classed as sandstone to a hard, close grained, glassy quartzite. The different conditions of texture are, however, so intermixed that it would be difficult to specify any distinct area as being prevailingly one or the other. In Jasper County the quartzite conditions appear to prevail in some sections, while at Rockland the rock is coarse grained and hard, but shows no glassy conditions. Again on the Biggam White Headright in the northern portion of Grime County the rocks change from a soft gray color, to a hard gray and brownish-gray sandstone with occasional blocks showing the characteristic texture of quartzite.[19]

The white and gray clays and gray sands associated with these sandstones occur interbedded and interstratified with the sandstone beds and vary in thickness from a few inches to several feet, some of the sand-beds reaching a thickness of twenty-five feet, while the clays rarely exceed six feet. Many of the sands show cross-bedding, some of the beds having a wavy or broken stratification showing the peculiar structure sometimes found along sandy coasts subject to wind and tide action and it is in these sands the beautifully opalized wood so characteristic of the Fayette beds is found in great abundance.

While the sands and clays have, with the exception of the opalized wood, yielded no fossils, the hard sandstones have given us a fauna scanty, it is true, but sufficient to connect the Fayette beds with the Eocene Tertiary.

In both Polk and Grime Counties plant remains have been found in the form of well preserved leaves. These, however, have not been described. Somewhat lower in the scale, in Polk and Brazos Counties, the remains of animal life occur. Four miles north of

[19] Fourth Annual Report Geol. Survey of Texas, 1892, p. 29.

Corrigan the section of a cutting on the Houston, East and West Texas Railway shows:[20]

1. Gray sand . . . . . 3 feet.
2. Light gray sandstone containing casts of *Corbula alabamensis* Lea, *Dentalium miuutistriatum* Gabb, var. *dumbli*, new var., *Venericardia planicosta* Lam., *Cytherea toruadonis* Harris, and *Calyptrophorus velatus* Con.[21] . . . . 1½ to 2 "
3. Durated gray sand or soft sandstone . . . . . 4 "

The Brazos County section containing fossils occurs at Dr. Williams' quarry about three miles east of Wellborn Station, on the Houston and Texas Central Railway. This section shows:[22]

1. Gray sands . . . . . 2 to 8 feet.
2. Thinly laminated, light gray sandy clays . . . 2 to 8 "
3. Broken sandstone with fossil casts . . . . . 2 "
4. Regular and even bedded sandstone . . . . . 6 "

Nos. 3 and 4 of this section contain *Bulimella kellogii*; *Pleurotoma* sp.; *Cancellaria penrosii* n. sp., Harris; *Yoldia claibornensis* Conrad; *Mactra* sp.; *Corbula alabamensis* Lea; *Siliqua simoudsi* n. sp., Harris; *Venericardia planicosta* Lam.; *Cytherea bastropensis* Harris, and *Turritella* sp.[23]

West of the Brazos River invertebrate fossils have been found in these beds, and from this it may be inferred that the same conditions hold good across the State.

The area occupied by the Fayette beds forms a narrow belt with extremely irregular and as yet badly defined boundaries extending from the bottom lands along the west side of the Sabine, westward to and beyond the Brazos, and while the greatest width of this belt may exceed fifteen miles, yet throughout its greater extent the average width is not over six to eight miles. Their southern margins dip beneath the overlying Frio clays and their northern borders rest upon the gypseous lignite-bearing clays and sands of the Yegua stage. The country underlaid by these sandstones and sands, particularly throughout the eastern portion of the territory in Jasper,

[20] Third Annual Report Geol. Survey of Texas, 1891, p. 115.
[21] Fourth Annual Report Geol. Survey of Texas, 1892, p. 46.
[22] Harris M.S., Monograph of Texas Tertiary Fossils.
[23] Harris M.S., Monograph of Texas Tertiary fossils.

Tyler and Polk Counties, is broken and hilly and generally rough, many of the hills rising in the form of steep side knobs to elevations more than 150 feet above the level of the river bottoms. The Neches River flows along the northern border of these sandstones for nearly twenty miles before breaking through them near Rockland, and along the whole of this distance the Fayette sands rise almost precipitously from near the river bank to altitudes varying from 120 to 275 feet above the river.

The dip of these beds is gentle, as a whole, but in many places faulting and sliding has obscured the true dip to such an extent that it is difficult to tell its exact rate. Extensive erosion also appears to have taken place throughout the whole area and long narrow projections of the overlying Neocene beds appear in many of the valleys. Along the eastern side of Billum's Creek, about two miles west of Colmesnil, a ridge of brown sand and quartz gravel and coarse pebbles, fifteen feet thick extends in a northeastern direction for several miles.

The Fayette sands of Eastern Texas tie up both stratigraphically and lithologically in the northern portion of Washington County, on the western side of the Brazos with those recently described as occurring from that point westward across the State by Mr. Dumble,[24] and may be considered but an eastern extension of the same.

There can scarcely be any doubt but that these beds, with the Frio clays and overlying Neocene ("Navasota Beds" of the Fourth Annual Report and Dumble's "Oakville Beds"[25]) formed what was understood by Hilgard, Hopkins, Loughridge and others to be the western, or Texas, extension of the Grand Gulf beds and considered of Miocene age. Whether the Neocene division as seen in the Navasota beds of the east or the Oakville beds of the west may be correlated with the Grand Gulf beds or not, future investigation must decide, but manifestly with the evidence at present before us no such correlation can be made as far as the Frio clays and Fayette sands are concerned. There can be no doubt as to their Eocene age, and moreover, a great hiatus occurs between the lowest Neocene beds and the highest Eocene deposits represented in the section as the whole of the Vicksburg and

[24] Fourth Annual Report Geol. Survey of Texas, 1892, pp. 9–15.
[25] Journal of Geology for Sept., 1894, pp. 557–558.

Jackson, and a considerable portion of the Claiborne stages are absent throughout the whole of this part of Texas.

Yegua Clays.

Immediately underlying the Fayette sands comes an extensive series of clays and lignites known to the Texas geologists as the Yegua clays. In the First Annual Report of the Survey these clays were considered as forming a portion of the Fayette beds of Prof. Penrose and were by him placed at the base of that division[26] and belonging to the same Grand Gulf series as the overlying gray sandstones of the Fayette sands as now known. The discovery of Eocene fossils in the overlying sandstones as well as in the clays themselves naturally relegated the whole to an older stage of deposition than that to which the Grand Gulf was supposed to belong. The wide lithological variation between the sandstones and thinly stratified and laminated lignitic sands and clays led to the separation of the two into independent stages more in keeping with their structure and evidently widely separated manner of formation and deposition and the designation "Yegua Clays" has been applied to them from their development on the river of that name.

These beds comprise a series of dark blue, brown and gray clays and blue-brown and gray sands and sandy clays. Extensive deposits of lignites are also found throughout the areas occupied by them. The clays are laminated, thinly stratified and massive and characterized by the great quantities of gypsum either in the form of selenite crystals or as irregular masses in a crystalline form distributed throughout the various beds. In the eastern portion of the area the laminated gypseous clays are more prevalent than farther west. In Angelina County these beds are thinly stratified blue clays containing small clusters of minute crystals of gypsum and occasional streaks or pieces of lignite which at their contact with the overlying Fayette sands on the Neches River have a thickness of over thirty-five feet. The section at Clark's Crossing shows:[27]

22.	Gray sandstone stained brown forming base of Fayette sands	3 feet.
23.	Thinly stratified or laminated blue clay with gypsum in crystals, to river level	35 "

[26] First Annual Report Geol. Survey of Texas, 1889, pp. 47–51.
[27] Third Annual Report Geol. Survey of Texas, 1891, p. 62.

The same characteristics prevail in Houston County where the base comprises a series of blue and brown laminated gypsum-bearing beds showing a section of:[28]

1. Ferruginous gravel talus from Cook's Mountain. 4 feet.
2. Thinly laminated brown clays . . . . . 4 "
3. Thinly laminated dark blue clays with interlaminæ of brown sand and crystals of selenite. 6 "
4. Fossiliferous brown sand, containing an extensive fauna, including, among others, *Anomia ephippioides* Gabb; *Volutilithes petrosa* Conrad; *Venericardia planicosta* Lam.; *Calyptrophorus velatus* Conrad,[29] and forming an intermediate bed of the marine stage . . . . . 10 to 15 "

Towards the western side of the same county these clays give place to massive brown sands and clays containing broken plant remains and sheet-like formations of crystalline gypsum. Still farther west, in Grime and Brazos Counties, gray sand forms the prevailing characteristics.

While towards the eastern end of the area it may be broadly stated that the clays are gypseous throughout and, as in the northern edge of Polk County, the overlying Fayette sands rest upon heavy beds of blue gypseous clays. The same conditions do not hold good along the contact between these divisions in the western portion. In Houston County, while the gypsum is pretty generally distributed throughout the whole of the series, the heavier deposits of that material occur towards the base; and in Brazos County the gypsum-bearing beds appear only at, or close to, the base of the division and is there overlaid by a series of dark blue clays containing broken plant remains, gray sands and sandy clays and the Fayette sands rest upon laminated or thinly stratified banded dark brown and yellow clays showing everywhere a heavy sulphur efflorescence.

The sands belonging to this series of deposits are blue, brown and gray in color and lie in beds from a few inches to over fifty feet in thickness. The gray sands form the prevailing type and occur over the whole area, but are better developed in Houston, Grime and

[28] Ibid., p. 17.
[29] Harris, M.S., Monograph of Texas Tertiary Fossils.

Brazos Counties than farther east. These are sometimes laminated and crossbedded but the greater portion is structureless. They are often saline, heavy incrustations of salt occupying the beds of dry pools and are of frequent occurrence during the summer months. In places they contain quantities of silicified wood of a dull, lustreless appearance, showing a strong contrast with the beautifully opalized woods of the overlying Fayette sands.

The lignite deposits of this division although well developed at many points are not so extensive, or nearly so regular, as those of the lignitic stage of the earlier Eocene. Most of the deposits range from two to four feet, although from six to ten feet are by no means rare.

Borings through these clays show them to have an aggregate thickness of nearly 1,000 feet. A well at Lamb's Springs, in Grime County, 999 feet deep passed through a series of clays, sands and lignites the whole depth, and another boring at the Agricultural and Mechanical College, five miles south of Bryan, in Brazos County, reached the 900 foot mark before the drill entered the underlying marine beds.

On the Brazos River the contact between the overlying Fayette sands and these clays is seen on the south side of the James Hope Survey in a section showing:

Fayette Sands.	1.	Gray sand and gravel	1 foot.
	2.	Gray sand containing great quantities of silicified wood. The wood is usually in large pieces—four to six feet in length, and bleached white.	5 feet.
	3.	Gray indurated sand with ledges of soft sandstone.	10 "
	4.	Gray sandstone jointed and thinly bedded, forming base of Fayette sands.	8 "
Yegua Clays.	5.	Dark brown lignitic clay, showing yellow bands from ¼ to ½ inch in thickness and coated with an efflorescence of sulphur, to water	20 "

No. 5 corresponds to the upper brown clay of Prof. Penrose's section of sulphur bluff in this neighborhood and a continuation of the section will give: [30]

	6.	Lignite	1 foot.
	7.	Gray sand	1 "

[30] First Annual Report Geol. Survey of Texas, 1889, p. 54–55.

8. Lignite . . . . . ½ foot.
9. Interbedded gray sand and chocolate and greenish clay, turned white in places on the surface . . 20 feet.

At Jones' bridge, about a mile further up the river, the same greenish clays are found in a section showing:

1. Yellowish gray sand . . . . . 32 feet.
2. Bluish-green, sandy clay containing fragments of lignite and breaking into ovoid blocks . . . . 46 "

and still farther up the river numerous shoals are formed of the same bluish-green clay. The section at this place is much obscured by river deposits of a much later age.[31] Here we find:

1. Brown river loam of sand and fine gravel . . . 18 feet.
2. Black sandy loam and clay loam mixed with brown sand and containing gravel and a few drift pebbles . . . . . 2 "
3. Pale blue clay . . . . . 8 "
4. Brown sand . . . . . 1 foot.
5. Coarse gravel containing water-worn, cretaceous shells . . . . . 2 feet.
6. Soft conglomeratic sandstone . . . . . 2 to 4 "
7. Bluish-green lignitic clay, breaking into blocks and containing broken plant remains, extending across the river and forming shoals . . . . . 6 "

Nos. 4, 5 and 6 of this section do not belong to these Yegua clays but form a later deposit filling a portion of the old river channel and are again seen near the mouth of the Little Brazos River, at which place they are found above the pale blue clay, No. 3 of this section.

No. 5 of the Hope section forms the uppermost bed of the Yegua clays in this part of the State but, as will be seen by the section already given, these clays do not occur in Polk County nor is there any trace of them along the contact in Houston or Trinity Counties where the uppermost beds are altogether gray sands and pinkish-gray clays, the latter carrying broken plant remains.

The basal portion of these clays, wherever seen, carry gypsum. In the eastern portion of the area this appears to be disseminated pretty generally through the whole series, although the crystals are notably

[31] Fourth Annual Report Geol. Survey of Texas, 1892, p. 48.

smaller in the upper than the lower beds. Westward from the Neches the gypsum crystals are, however, almost exclusively confined to the fifty or sixty feet at the base.

The base of these clays may be seen in a bluff on the Brazos River about 500 yards south of the mouth of the Little Brazos, with the following section :[32]

	1. Black soil	2 feet
	2. Brown loam with limy concretions . . .	25 feet
	3. Fine brownish-yellow sand with occasional streaks or pockets of gravel	15 feet
	4. Gravel, with unknown cretaceous shells .	2 to 4 feet
Yegua clays	5. Pale blue clay unfossiliferous	5 feet
	6. Dark green sand showing fossils in lower portion	2 to 5 feet
Marine Beds.	7. Dark colored laminated sandy clay containing *Terebra houstonia* Harris; *Levifusus trabeatoides* Harris n. sp.; *Pseudoliva vetusta* var.; *Pseudoliva vetusta* var. *pica*; *P. vetusta*, var. *clausa*; *Trigonarca corbuloides*, Con.; *Pleurotoma (Pleurotomella) quasites*, Harris; *Nucula magnifica*, Con.; *Leda opulenta*, Con.; *Latirus moorei*, Gabb.; *Corbula alabamensis*, Lea; *Venericardia planicosta*, Lam; *Phos texana*, Gabb., var.; *Natica arata*, Gabb.; *Natica semilunata*, var. *janthinops* new var.; *Sigaretus inconstans*, Ald.; *Yoldia aldrichiana*[33]	4 feet
	8. Ferruginous sandstones	8 inches
	9. Same as No. 7.	

In this section the gypseous clays are not seen nor do they appear anywhere in the river banks. This, however, may be expected as their position there is obscured by broad, deep deposits of river alluvium which cover wide areas and form the bottom lands of the Brazos. East of the Little Brazos these clays are found occupying their proper position at several places. A section seen on the line of the Houston and Texas Central Railway near Elm Creek, on the south side of Robertson County, shows :[34]

[32] Fourth Annual Report Geol. Survey of Texas, 1892, p.
[33] Harris M. S., Monograph of Texas Tertiary Fossils.
[34] Fourth Annual Report Geol. Survey of Texas, 1892, p. 50.

1. Brownish-yellow sand and gravel . . . . . 5 to 6 feet
2. Brown coffee-colored clay with great quantities of gypsum crystals . . . . . 2 to 6 feet
3. Brown and yellowish-brown sand and ledges of indurated sand or ferruginous sandstone, the sands containing *Anomia ephippioides*, Gabb; *Plicatula filamentosa* Conrad; *Spirorbis leptostoma*, Swain; *Volutilithes petrosa* Conrad; and other fossils,[35] over 40 feet

Going eastward the Navasota River section is practically the same as on the Brazos. Neocene beds occur a short distance north of Rock Creek, in Grime County. The Frio clays do not appear anywhere along this river, but overlaps of the Neocene Navasota beds (Oakville beds of Dumble) completely cover them. The Fayette sands extend to about the mouth of Gibbon's Creek, or a short distance above, and from there to near the northwest corner of Madison County the whole country is occupied by the gray sands, greenish blue lignitic clays and lignites of the Yegua showing practically the same sections as those found along the Brazos. Very few sections of any value are found along this river, but the few obtainable, supplemented by those farther inland, show the general sequence here given. The gypseous clays are found in this region lying close to the base and occupying the same position as near Elm Creek on the western side of Brazos County.

The Trinity River section shows the typical Yegua clays in many of the bluffs. A section at Hyde's Bluff, in the southwestern portion of Houston County, shows:

Yegua Clays

1. Dark yellowish-brown clayey loam . . . . . 8 feet
2. Conglomerate of nodular iron ore, silicious pebbles, silicified wood, coarse brown sand and fine gravel. 2 feet
3. Dark blue sandy clay with iron pyrites. . . . 10 feet
4. Lignite . . . . . 2 inches to 2 feet
5. Light grayish-blue sand and gray clay interlaminated . . . . . 10 feet
6. Lignitic . . . . . 2 to 4 feet
7. Dark purple colored clay . . . . . 1½ feet
8. Gray sand containing rounded and flat oval shaped concretions of indurated gray sand, to water . . . . . 4 feet

[35] Harris' MS. Monograph of Texas Tertiary Fossils.

The base of these beds is seen at Alabama bluff some twenty miles farther up the river, where a bed of blue clay with gypsum crystals occurs in contact with the underlying fossiliferous sands of the Marine beds. This section shows :[36]

Yegua Clays	1. Black sandy loam	5 feet
	2. Gravelly conglomerate	2 feet
	3. Laminated blue clay with gypsum	2 to 5 feet
Marine Beds	4. Fossiliferous greenish-blue clay	4 feet
	5. Green sand	5 feet
	6. Clay ironstone	10 inches
	7. Fossiliferous clay, to water	5 feet

No. 3 of this section shows the base of the Yegua clays as found on the Trinity River.

Eastward towards the Neches River the deposits belonging to this stage assume more and more the same structure and conditions of deposition as found in Angelina and the other counties in the eastern portion of the area.

The positions of the sections given show approximately the northern boundary of the area occupied by these Yegua clays. The line may be traced by the outcroppings of the gypseous clays and sands from the Sabine River, near Sabine Town, in a generally northwestern direction as far as the Angelina River, near the mouth of the Atoi Creek, in Cherokee, and thence southwesterly, crossing the Neches near Weches Post Office, passing through the eastern side of the town of Crockett, crossing the Trinity at Alabama Bluff, the Navasota River near the northwest corner of Madison County and the Brazos at the locality shown in the section already given. To the south they are circumscribed by the overlying Fayette sands.

Unlike the rough, hilly region occupied by the Fayette sands, the country occupied by the Yegua clays is generally flat. Sand hills and ridges occur in several localities, but throughout the greater portion level, prairie-like conditions prevail.

The fauna of these deposits throughout east Texas is scanty in the extreme. Of the vertebrates only one specimen, the portion of the lower jaw of a species of *Crocodilus*, has been obtained, and that from a well at Bryan, while no invertebrate fossils have been found anywhere east of the Brazos except at the base of the beds on that

[36] Third Annual Report Geol. Survey of Texas, 1891, p. 15.

river, although the beds found on the Yegua are fossiliferous, and those found farther west are reported to have yielded a very fair number of that class of animal life. Plant remains are numerous, both in the form of silicified and lignitized wood, and leaves of many kinds are extremely abundant. None of these have yet been studied, but from the fact that silicified palm wood occurs, although sparingly, among the upper gray sands, the climate was slightly warmer than at present.

The general conditions of deposition during this period appear to have been those of a marsh subject to periodical deep, wide-spread inundation and a gradual, though slow, subsidence. The Marine beds lying to the north evidently stood at a much higher relative elevation than at present. Their southern boundary is everywhere carved into bold outlines and deeply indented bays showing at places steepsided and shelving bluffs where the Yegua clays rest unconformably upon and against them, and from which boulders of fossiliferous sandstones have fallen and are now found in considerable numbers imbeded in the sands and lying between one and two miles from the line of contact. At other places where bay-like conditions prevailed, the placid waters of the flooded areas favored a calmer deposition and growth of plant life; the lines of contact are not so far apart in their general conditions and range of dip.

Instances of the former conditions are many. Typical illustrations of this bluff-like shore line may be seen at Cook's Mountain, in Houston County, and near Elm Creek, north of Bryan, in Brazos County. At Cook's Mountain the hill rises almost abruptly from the level of Milam branch to an elevation of 130 feet above the stream bed, and is capped with fifty feet of altered glauconitic fossiliferous sandstone. The gypseous clays of the Yegua stage are found only on the south side of the stream, and rest upon a heavy bed of fossiliferous sand projecting from the side of the mountain. The Brazos section also shows this want of conformity in quite as strong a manner. The Marine beds occur capping the higher hills ten miles north of College Station and lying at an elevation of 375 feet, while College Station has an altitude of 350 feet. The dip of the Marine beds in this section closely approaches 75 feet per mile and these beds, after allowing for the difference of elevation, should have been found at 725–750 feet in the well bored at the college. The bore, however, was over 900 feet deep before fossils occurred,

and then they corresponded to a lower division of the Moseby Ferry section than those found near Elm Creek. Moreover, on the south prong of Thompson's Creek, about eight miles north of the well boulders and of ferruginous fossiliferous sandstone occur imbedded in the yellowish gray sandy clay of the Yegua beds.

The correlation of any of these three stages—the Frio clays, Fayette sands and Yegua clays—with the deposits of Louisiana lying immediately to the east is attended with more or less difficulty and doubt from the fact that little or no work, and that of the most general character, appears to have been done in that portion of the State. The Grand Gulf, according to both Hilgard and Hopkins, appears to have embraced the upper two and at least a portion of the Yegua clays besides the upper calcareous sandstones, and was, according to these writers, above the Vicksburg. The lower portion of the Yegua clays were apparently considered by them to be of Jackson age. Dr. Hilgard says, after describing the Grand Gulf formation: "On the Sabine River, too, the upper portion of the profile is pretty correctly reproduced. At the base of the Grand Gulf rocks we find on the Bayou Taureau a seam of shell-limestone with Vicksburg fossils. We then pass over lignito-gypseous strata to Sabine Town, Texas, where we see about seventy feet of these overlying ledges of blue fossiliferous limestone alternating every two or three feet with what would be green sand marl like that of Vicksburg had not the lime of the numerous shells, of which it contains casts, been removed by subsequent dissolution. So far as I have seen, the usual leading fossils of Vicksburg are wanting here, while the greater sandiness of the materials, as well as the prevalence of shallow sea bivalves indicates their deposition in shallower water. As we proceed northward from Sabine Town lignitic clays and lignite alone separate, and sometimes altogether replace the limestone ledges which themselves become poorer in fossils as we approach the northern edge of the formation."[37]

According to Hopkins the Jackson beds consist of marine strata with characteristic fossils of lignite and non-fossiliferous beds and laminated sands and clays and among the marine beds massive beds of clay full of selenite.[38]

[37] Geol. Reconn. of La., American Journal of Science, Second Series, Vol. XLVIII, 1869, p. 338.

[38] First Annual Report Louisiana State Geol. Survey, 1869, pp. 94-96; Second Annual Report Louisiana State Geol. Survey, 1871, pp. 7 to 84.

With the exception of the lignite and characteristic Jackson fossils this description would answer the Texas Frio clays as well as the Yegua clays. Besides their contact with and underlying the Neocene Navasota beds (Oakville beds) would in the absence of the Vicksburg deposits closely correspond with the Frio clays. Their extension to Sabine Town, however, where they would meet the Marine beds of the Texas section would naturally lead to the inference that both the Fayette sands and Yegua clays are absent in Louisiana.

This interpretation of the work done in Louisiana can hardly be accepted, and until more information is obtainable the correlation of the beds in these States must be left as an unsolved problem.

Marine Beds.

Lying immediately north of the Yegua clays we have an extensive series of green sands, green sand marls, altered green sands containing thin strata of carbonate of iron, indurated altered fossiliferous greed sand, green fossiliferous clays, glauconitic sandstones and clays stratified, black and gray sandy clays, black and yellow clays with limy concretions, brown and yellow fossiliferous sands with occasional deposits of black sand containing gypsum crystals, and at wide intervals small deposits or thin seams of lignite. Extensive deposits of ferruginous sandstone and limonite, both in laminated and nodular form, occur in the upper divisions. The prevailing deposits, however, are the green sands in their several characters. The clays are of minor importance and exist generally as thin beds of irregular distribution interstratified with the sands. The lignites are usually not more than a few inches thick and are never continuous, and the limonite deposits occur as nodular ores lying in heaps or mounds among the grayish-brown and gray sands or as laminated ores covering wide areas of the surface, particularly throughout Cherokee, Anderson, and Rusk Counties. These are the iron-ore fields of East Texas, and constitute the series of beds known as the Marine beds of the Texas section and have a total thickness of 650–700 feet.

Stratigraphically these beds occupy a position intermediate between the overlying Yegua clays and the lignitic stage, and form the uppermost division of Penrose's timber belt or Sabine River beds.[39] In the reports of the Texas Geological Survey these beds have been

[39] First Annual Report Geol. Survey of Texas, 1889, pp. 22–47.

divided into two groups or series, the basal from its greatest development in Cherokee County was called, tentatively, the "Mount Selman" series, and the upper, from its typical development in Houston County, received the name of the "Cook's Mountain" series. This division was made partly on lithological grounds, the lower or Mount Selman series being generally heavier bedded and made up throughout its greater extent of dark green and brown sands and sandstones, with very thin seams of iron and while fossiliferous to a greater or less extent the fossils are much fewer than in the upper or Cook's Mountain series, and exist almost altogether in the form of casts. On the other hand the upper series, which includes the highest beds of the Marine stage, is to a great extent loose sands and clays with heavy beds of laminated iron ore and contains a large and beautifully preserved fauna.

While probably the distinctive lithological differences between the upper and lower divisions of these beds may not hold good at all points and it may be difficult under the present existing conditions to draw the exact line between them yet the general paucity of life in these lower beds appears in marked contrast with the teeming life of the upper.

In the northeastern portion of the State, where in Cass, Marion and Morris Counties, these beds appear only as remnants of a widespread cover, or as isolated patches forming the low hills of the region, nothing but the lower beds are seen. These are brown, brownish-yellow and green in color, indurated and moderately hard sands and sandstones, and have till now shown no trace whatever of animal life. In Harrison County the greenish-yellow sandstones seen near the Marshall waterworks pumping station show occasional casts of *Venericardia planicosta* Lam., and the same form has also been found near Hynson's Springs, in the same county. These lie at the base of the Marine beds as shown in the section at the pumping house.

	1. Brown gravelly sand	5 feet
Marine	2. Laminated iron ore and ferruginous sandstone .	1½ feet
	3. Greenish-yellow altered glauconitic sandstone with casts of *Venericardia planicosta*. . . .	4 feet
Lignitic	4. Laminated or thinly stratified red and white sands and sandy clays forming uppermost bed of the lignitic in this portion of the county .	45 feet

Coming westward the same unfossiliferous condition of these lower beds is seen along the south side of the Sabine River in Gregg County, in a section at Iron Bridge Post Office. Here the bluff shows :

1. Surface dark brown or coffee-colored sand with broken fragments of sandstone . . . . . 6 feet
2. Heavy bed of yellowish-brown sandstone . . . . 6 feet
3. Brown sand . . . . . 6 feet
4. Brown or yellowish-brown sandstone similar to No. 2, but softer and containing alternate strata of brown sand . . . . . 10 feet
5. Brown or yellowish-brown sand containing occasional small nodules or concretions of iron . . 12 feet

In the Mount Selman region, in Cherokee County, the section shown along the line of the Tyler Southeastern Railway is more sand than sandstone, and while containing a few fossil casts cannot be called fossiliferous throughout. The general section shown from Jacksonville to Bullard gives :[40]

1. Gray surface sand . . . . . 10 feet
2. Brown sand, ferruginous pebbles and iron ore . . 15 feet
3. Mottled sand . . . . . 10 feet
4. Brownish-yellow sand . . . . . 4 feet
5. Brownish-yellow standstone . . . . . 10 feet
6. Alternate strata of laminated iron ore and brown sand, the ore generally from two to ten inches and the sand from one to two feet thick . . . . 8 feet
7. Dark green sand containing casts of small bivalve shells . . . . . 5 feet
8. White clayey sand . . . . . 1 foot
9. Dark green, nearly black, sand containing thin seams of ferruginous material near top, and also containing small fish teeth and *Venericardia planicosta* and *Sphærella antiproducta* in very small numbers . . . . . 12 feet
10. Brown sand . . . . . 10 feet
11. White sand . . . . . 10 feet

[40] Third Annual Report Geol. Survey of Texas, 1891, p. 53.

12. Alternate strata of brown sand and laminated iron ore, one generally wavy and not more than two to six inches with sand from one to two feet thick . . . . . 20 feet
13. Pale-blue and brown clay mottled in places and laminated in others . . . . . 15 feet
14. Alternate strata of glauconitic brown sand and iron ore, the ore generally irregularly deposited, laminated and silicious and not exceeding six inches to one one foot, the sand from six inches to two feet thick . . . . . 55 feet
15. Brown sand forming surface at Bullard, altered green sand changing to yellow a few feet under ground . . . . . 40 feet
16. Dark green sand containing a few fossil shells and fish teeth . . . . . 24 feet

Lignitic
17. Lignite or "black dirt" containing leaves . . . 2 feet
18. Dark lignitic clay . . . . . 5 feet

Nos. 17 and 18 of this section belong to the lignitic beds.

On approaching the Brazos the base of these beds is again seen about two miles south of Calvert, in Robertson County, where they form a ridge of brownish-yellow sandstone of very similar texture and appearance as the sandstones in Harrison County, and appear to be altogether unfossiliferous. Where the International and Great Northern Railway crosses the Brazos River these beds are again seen in the following section :

1. Yellow sandy clay with limy concretions . . . . 20 feet
2. Brown sand and sandstones interstratified . . . 4 to 6 feet
3. Dark green, almost black, unfossiliferous sand . 5 feet
4. Thinly laminated dark green sand . . . . . 6 feet
5. Irregular belt of ferruginous sandstone . . . . . ½ to 1 foot
6. Dark green, almost black, sand, to water . . . . 3 feet

The lower and upper divisions grade into each other so imperceptibly that so far as the actual division is lithologically concerned any line of separation would be but a very arbitrary one. The wide distinction, however, in the state of preservation and condition of the contained fossils might possibly enable us to approximately indicate the limits within which the several beds might be assigned to each. As already stated the fossils of the lower or Mount Sel-

man beds exist almost wholly in the form of casts, whereas, on the other hand, the fauna of the Cook's Mountain, or upper beds, is beautifully preserved, many being in a very perfect condition and exist in great numbers.

In crossing the whole series from north to south the first indication of well preserved fossils in the east occurs in the southern portion of Rusk County, near Mount Enterprise, and on Stevens branch, a tributary of Shawnee Creek. Farther west they are found in Cherokee, south of Jacksonville, a few miles west of Palestine, in Anderson, near the mouth of Elkhart Creek, in Houston, near Centreville, in Leon, and south of Franklin, in Robertson County, and near the Burleson County north line on the Brazos. These localities may therefore be taken as approximately indicating the northern line of the "Cook's Mountain" or upper series of the Marine beds as known in Texas, but it must be remembered that on the eastern side very extensive erosion has taken place, and probably these beds may have extended much farther north. At any rate the line may be considered as only an approximate division of what evidently constitutes but one stage of the Eocene.

To the south of this approximate boundary we have an extensive series of green sands, glauconitic sands, ferruginous sandstones, clays and iron ores in most respects similar to those lying north of it. The green sands, as a general thing, are less altered and more glauconitic, the sands less indurated and the iron ore deposits much heavier and almost altogether laminated. The fauna is very much richer both in species and number of specimens, and the fossils all in a good state of preservation and easily obtainable.

While these beds are known to exist in isolated hills throughout the counties of Rusk, Nacogdoches, San Augustine and Sabine Counties, lying east of the Angelina River, no satisfactory sections have been obtained and only a few of the fossils from these areas have been determined. According to Professor Heilprin[41] these include *Venericardia transversa* Lea, *Crassatella texana* Heilp., *Pecten deshayesii* Lea, *Ostrea alabamensis* Lea, *O. sellaformis* Lea and var. *divaricata* Lea, from San Augustine County. *Pectunculus idoneus* Con., and *Ostrea sellaformis*, var. *divaricata* Lea, from Nacogdoches County,

[41] Proceedings Acad. of N. S., Phila., Oct. 1890, pp. 393–404.

have been identified by Mr. Harris.[42] *Pseudoliva vetusta* Con., *Venericardia planicosta* Lam., have also been obtained from the bluff at Sabine Town. The fossils found in Rusk and Nacogdoches Counties are well preserved and enclosed in a bluish-green indurated marl and hard to extract in a condition suitable for identification. The Sabine Town fossils are enclosed in a brown sand. *Scutella caput-sinensis* Heilpr., also occurs in San Augustine as well as west of the Angelina at McBee's School and near Alto, in Cherokee County.

West of the Angelina River the most important section obtained is that at Alto, in Cherokee County. This section embraces a series of green sands and altered glauconitic sands and sandstones lying close to the top of the "Cook Mountain" beds, and forms the uppermost Eocene deposit in this portion of the State. The section combines the whole of the green sand deposits from Alto, eastward to the edge of the Angelina River "bottom lands," eight or ten miles farther east, and the whole or the greater portion of the section may also be taken as representative of the structure of the country from Alto southwestward to the Neches. The section shows:

1. Gray sand . . . . . 5 to 20 feet.
2. Ferruginous sandstone . . . . . 1 foot.
3. Iron pyrites and lignite . . . . . ½ to 1 foot.
4. Laminated iron ore and brown sand . . . . 10 to 15 feet.
5. Brown and yellowish-brown altered glauconitic sand with streaks and nodules of calcareous matter and containing *Terebra houstonia* Harris, n. sp., *Pleurotoma (Surcula) gabbii* Conrad, *Ostrea sellaformis*, var. *divaricata* Lea, *Pinna*, sp., *Trigonarca pulchra* Gabb, *Pseudoliva vetusta* Con., *Volutilithes petrosa* Con., *Laticus moorei* Gabb, *Corbula texana* Harris, *Corbula aldrichi*, var. *smithvillensis* Harris, *Dentalium minutistriatum* Gabb, *Venericardia planicosta* Lam., *Venericardia rotunda* Lea, *Clavilithes*

[42] Harris' MS., Monograph Texas Tertiary fossils.

NOTE.—I have not visited any of the localities referred to in Rusk, Nacogdoches and Sabine Counties. Rusk and Nacogdoches Counties were examined in 1890 by Mr. J. B. Walker. His sections can be seen in the Second Annual Report, Geol. Survey of Texas, 1891, under these county headings. They appear to me to be slightly unreliable. The Sabine Town fossils were sent from there by the Postmaster to Mr. Dumble at his request. K.

regexa Harris, n. sp., *Phos texana* Gabb var., *Distortio septemdentata* Gabb, *Solarium acutum*, var. *meekanum* Gabb, *Terebellum*, *Calyptrophorus velatus* Con., *Mesalia claibornensis* Con., *Anomia ephippioides* Gabb, *Cerithium vinctum* Whitf., *Pecten claibornensis* Conrad, *Pecten deshayesii* Lea, *Plicatula filamentosa* Con., *Cytherea texacola* Harris, *Crassatella texana* Heilp., *Turritella nasuta* Gabb, and many of these in profusion . . . . . 6 feet.

6. Yellowish-brown and grayish-brown often grayish-green indurated green sands containing most of the fossils found in No. 5 and an additional fauna of *Pleurotoma* (*Drillia*) *nodocarinata* Gabb, *Volutilithes petrosa* var. *indenta* Conrad, *Caricella subangulata* var. *cherokeensis* Harris, *Cassidaria brevicostata* Ald., *Pholadomya claibornensis* Ald., *Byssoarca cuculloides* Con., *Martesia texana* Harris, n. sp. *Dentalium minutistriatum* var. *dumblei*, n. var., *Protocardium nicolletti* Con. var., *Natica newtonensis* Ald., *Natica limula* var., *Rimella texana*, var. *plana*, new var. *Cancellaria panones* Harris, n. sp., *Clavilithes* (*Papillina*) *dumosa*, var. *trapaquara* Harris, *C. humerosa*, var. *texana* Harris, *Cassidaria brevicosta* Ald., *Turritella dutexta* Harris, *Scutella caput-sinensis* Heilpr., and fish teeth . . . . . 20 feet.

7. Green sands with casts of fossils . . . . . 6 "

8. Brown altered glauconitic sandstone with casts of fossils . . . . . 30 "

9. Green sand with fish teeth and *Conus sauridens* Con., *Anomia ephippioides* Gabb, *Byssoarca cuculloides* Con., *Trigonarca pulchra* Gabb, *Volutilithes petrosa* Con., *Volutilithes precursor* Dall, and others belonging to Nos. 5 and 6 . . 8 "

The localities from which these fossils were obtained all lie between Alto and the Angelina River. The specimens are, as a general thing, very plentiful, and in most localities easily freed from the

enclosing matrix, those in the brownish-yellow sand being often free.

As already stated these beds can be easily traced from this point in a southwesterly direction for many miles, the bed containing the *Scutella caput-sinensis* forming a particularly well marked horizon. No Scutellæ, however, have yet been found in Houston County or to the west, although plentiful from the Neches eastward to San Augustine. Four miles west of Alto, a range of flat-topped steep-sided hills show a general section of:

1. Gray sand . . . . . 20 feet.
2. Indurated yellow sand containing numerous Scutellæ and *Ostrea sellæformis*, var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Pseudoliva vetusta* Con., *Venericardia planicosta* Lam., and *Cytherea tornadonis* Harris[43] . . . . . 20 feet.
3. Red sand with casts of fossils . . . . . 15 "
4. Green sand with casts of fossils visible . . . . 4 "

Crossing the Niches into Houston County the section as shown in a well near Robbins' Ferry shows:

1. Gray sand . . . . . 6 inches to 1 foot.
2. Laminated iron ore . . . . . 4 inches to 10 inches.
3. Indurated yellow fossiliferous sandy marl containing *Ancilla* (*Olivula*) *staminea* Con., *Ostrea sellæformis*, var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Venericardia planicosta* Lam., and *Crassatella trapaquara* Harris[44] . . . . . 2 feet.
4. Yellow sand . . . . . 10 "
5. Clay . . . . . 2½ "
6. Fossiliferous green sandy clay containing *Anomia ephippioides* Gabb, *Venericardia planicosta* Lam., *Rimella texana*, var. *plana*, new variety, *Calyptrophorus velatus* Con.[45] . . . . . 5 to 6 "
7. Red clay . . . . . 3 to 4 "
8. Blue marl with fossils same as No. 6 . . . . . 18 "
9. Brown sand to bottom of well . . . . . 5 "

At the crossing of the San Pedro Creek by the Rusk road in the

[43] Harris, MSS., Monograph of Texas Tertiary Fossils.
[44] Harris Mss. Monograph of Texas Tertiary fossils.
[45] First Annual Report Geol. Survey of Texas, 1889, p. 34.

same county, the south bank of the creek shows a section of

1. Gray sands . . . . . 25 feet
2. Brown sand and altered green sand with stratified ferruginous material and thin laminæ of iron ore near base . . . . . 6 feet
4. Yellow indurated fossiliferous altered green sand packed with shells . . . . . 20 feet

The eastern portion of Hurricane Bayou forms the approximate southern boundary of the Marine beds for six or eight miles east of Crockett. Here, when the Bayou is dry, or the water at a low stage, an extremely interesting fauna may readily be obtained. Among the fossils found we have *Terebra texagyra* Harris var., *T. houstonia* Harris n. sp., *Conus sauridens* Con., *Pleurotoma* (*Surcula*) *gabbii* Con., *Pl. heilpriniana* H. n. sp., *Pl.* (*Drillia*) *nodocarinata* Gabb., *Pl. childreni* Lea, var. *bilota*, H., *Pl. huppertzi* Harris, n. sp. *Pl. megapis* H. n. sp., *Pl.* (*Drillia*) *texacona* Harris, *Pl.* (*Drillia*) *texana* Gabb., *Pl. vaughani* var. Harris, *Pl. retefera* H., *Pl.* (*Mangelia*) *infans* var. H., Mr. *Olivella bombylis* var. *burlesonia* H., *Ancilla* (*Olivula*) *staminea* Con., *Anomia ephippioides* Gabb., *Plicatula filamentosa* Con., *Peeten* sp., *Pinna* sp., *Pectunculus idoneus* Con., *Pseudoliva vetusta* Con. var., *Volutilithes petrosa* Con., *Cariella demissa* var. *texana* Gabb., *Marginella seminoides* Gabb., *Lapparia pactilis* var. *mooreana* Gabb., *Turricula* (*Conomitra*) *texana* H., *Terebra amana* Con., *T. costata* Lea, var., *Latirus moorei* Gabb., *Corbula alabamensis* Lea, *Dentalium minutistriatum* Gabb., *Cadulus subcoarcuatus* Gabb., *Venericardia rotunda* Lea, *V. planicosta* Lam., *Crassatella texana* H., *Cytherea tornadonis* H., *Clavilithes* (*Papillina*) *dumosa* var. H., *C. trapaquara* H., *Fusus mortoni* var. *mortonopsis* Gabb, *Clavilithes humerosa* var. *texana* H., *Phos texana* Gabb var., *Distortio septemdentata* Gabb, *Cassidaria planoteeta* Ald., *Solarium acutum* var. *meekanum* Gabb, *Natica acuta* Gabb, *Natica limula* var., *Sigaretus declivis* Con., *Mesalia claibornensis* Con., *Belosepia ungula* Gabb, *Spirorbis leptostoma* Swain, and the corals *Occulina* Heilpr., *Turbinolia pharetra* Lea, *Trochosmilia mortoni* Gabb and Horn, and *Endopachys maclurii* Lea.

These fossils all occur in an altered green sand of a brownish yellow color in places indurated into hard slabby sandstones, but the greater portion soft. This overlies a dark green sand and clay as

seen in a well at Mr. K. Jones' house, nearly half a mile north of the Bayou. The section of the well shows :

1. Yellowish-brown sandy clay . . . . . 6 feet
2. Joint clay . . . . . 6 feet
3. Thinly laminated black fossiliferous sand . . . . . 4 feet
4. Bluish green fossiliferous sands . . . . . 14 feet

Nos. 3 and 4 hold fossils closely corresponding to those found on the Bayou with a few additional species.

West of Crockett, about two miles, we have Cook's Mountain, an isolated hill rising about 460 feet above sea level and showing a more or less precipitous face on every side. This face, however, is marked by a series of benches and the general section shown on the eastern side, from Milam branch to the top of the mountain, shows :

1. Brown ferruginous sandstone with occasional casts of a small bivalve . . . . . 10 feet
2. Yellow-colored crossbedded altered glauconitic sand 40 feet
3. Brown sand and sandstone with occasional seams of ferruginous material . . . . . 55 feet
4. Brown ferruginous sandstone containing *Ostrea sellæformis* var. *divaricata* Lea, and *O. alabamensis* Lea in considerable numbers . . . . . 10 feet
5. Iron ore . . . . . 1 foot
6. Brown sand containing *Bulimella kellogii* Gabb., *Terebra texagyra* var. Harris, *T. houstonia* Harris, n. sp., *Conus sauridens* Con., *Pleurotoma (Surcula) gabbii* Con., *Pl. (Cochlespira) engonata* Con., *Pl. (Drillia) nodocarinata* Gabb., *Pl. (Drillia) texana* var. *pleboides* Harris, *Pl. (Mangelia) infans* var., *Pl.* sp., *Ancilla (Olivella) stamínea* Con., *Ostrea alabamensis* Lea, *O. sellæformis* var. *divaricata* Lea, *Anomia ephippioides* Gabb., *Plicatula filamentosa* Con., *Avicula* sp., *Pinna* sp., *Pseudoliva vetusta* Con. var., *Volutilithes petrosa* Con., *V. petrosa*, var. *indenta* Con., *V. precursor* Dall. var., *Caricella subangulata var. cherokeensis* Harris, *Lapparia pactilis* var. *nooreana* Gabb., *Latirus nuorei* Gabb., *Cornulina armigera* Con., *Corbula alabamensis* Lea,

Venericardia planicosta Lam., *Cytherea texacola* Harris, *Clavilithes regexa* Harris, n. sp., *Phos texana* Gabb. var., *Distortio septemdentata* Gabb., *Scala*, *Natica arata* Gabb., *N. limula* var., *Sigaretus declivis* Con., *Calyptrophorus velatus* Con. *Turritella nasuta* var. *houstonia* Harris, *T. nasuta* Gabb., *Belosepia angula* Gabb., and the corals *Occulina* Heilpr., *Turbinolia pharetra* Lea, *Trochosmilia mortoni* Gabb and Horn, and *Endopachys maclurii* Lea. A number of fish teeth also occur in this bed . . 15 feet

Going north from the Hurricane Bayou localities we find fossiliferous indurated brownish-yellow and green marly sands at Hannon's mill, and on the Murchison prairie and eastward. A section of Murchison prairie shows:

1. Black soil . . . . . 1 to 2 feet
2. Brownish-yellow altered green sand . . . . . 4 feet
3. Brown sand containing *Ostrea alabamensis* Lea, *Ostrea selliformis* var. *divaricata* Lea, *Pecten deshayesii* Lea, *Cerithium vinctum* Whitf., *Venericardia alticosta* var. *perantiqua* Con., *Venericardia planicosta* Lam., and *Cytherea texacola* Harris, *Volutilithes petrosa* var. *indenta* Con., *Cornulina armigera* Con . . . . . 4 feet
4. Bluish green marly sand indurated and containing similar fossils to No. 3, as well as *Corbula aldrichi* var. *smithvillensis* Harris, *Crassatella texana* Heilpr., *Crassatella trapaquara* Harris, and *Cytherea texacola* H . . . . . 10 feet

Still farther north, at Elkhart, the same section appears. A section at Elkhart wells shows:

1. Brown and black plastic clays containing irony pebbles, silicified wood and calcareous nodules . 10 feet
2. Gray and yellow brown clays in thin laminæ . . . 5 feet
3. Dark brown altered green sand with fossil casts . 1 foot
4. Gray laminated plastic clays . . . . . 3 feet
5. Green sand, hard for eight or ten inches, full of shells and interbedded with greenish black clay 4 feet

This bed, No. 5, contains *Plicatula filamentosa* Conrad, *Pinna* sp.,

and other fossils similar to those occurring in the dark green sand and greenish black clay as seen in the Jones' well near Hurricane Bayou, where it has a known thickness of fourteen feet. Brown clays with pebbles occur near Hague's gin four miles northeast of Jones' well, and gray and bluish yellow clays with calcareous nodules can be traced as far south as the same place where they have a thickness of five feet and are underlaid by the same brown sand, five to six feet thick, as found in No. 3 of the Elkhart section.

On the Trinity River we have the section well exposed in a series of bluffs extending from Alabama Bluff on the south to the northern edge of Houston County. The section at Alabama Bluff gives the contact with the overlying Yegua clays and shows a slight unconformability between the two stages. Omitting the upper portion of the section we have:

4. Fossiliferous greenish-blue clay . . . . . 4 feet.
5. Green sand altered to a brownish-yellow sand with thin strata of ferruginous material interstratified and containing *Volvula conradiana* Gabb, *Conus sauridens* Conrad, *Pleurotoma* (*Surcula*) *gabbii* Con., *Pl.* (*Cochlespira*) *engonata* Con., *Pl.* (*Surcula*) *moorei* Gabb, *Pl.* (*Drillia*) *nodocarinata* Gabb, *Pl.* sp., *Ancilla* (*Olivula*) *staminea* Con., *Anomia ephippioides* Gabb, *Plicatula filamentosa* Con., *Trigonarca pulchra* Gabb, *T. corbuloides* Con., *Leda honstonia* Harris, *Pseudoliva vetusta* Con. var., *Volutilithes petrosa* Con., *Caricella demissa*, var. *texana* Gabb, *Turricula* (*Conomitra*) *texana* Harris, *T. polita* Gabb, *Latirus moorei* Gabb, *Corbula alabamensis* Lea, *Cadulus sub-coarcuatus* Gabb, *Fusus mortoni*, var. *mortonopsis* Gabb, *Clavilithes penrosei* Heilprin, *Phos texana* Gabb, *Distortio septemdentata* Gabb, *Cassidaria planotecta* Ald., *Solarium bellastriatum* Con., *Natica arata* Gabb, *N. limula* Con., *Mesalia claibornensis* Con., *Turritella nasuta* Con., *Spirorbis leptostoma* Swain, *Turbinolia pharetra* Lea . . . 5 to 6 feet.
6. Ferruginous sandstone with iron-ore . . . . 1 to 2 "
7. Green sand and ferruginous material same as No.

5 and containing same fossils with addition of *Pleurotoma heilprinianа* Harris, n. sp., *Ostrea selleformis*, var. *divaricata* Lea, *Pinna*, sp., *Byssoarca cucullоides* Con., *Lapparia pactilis*, var. *mooreana* Gabb, *Venericardia planicosta* Lam., *Crassatella texana* Harris, *Cytherea texacola* Harris, *Clavilithes* (*Papillina*) *dumosa*, var. *trapaquara* Harris, *Natica* sp., *Turritella nasuta*, var. *houstonia* Harris, *Belosepia ungula* Gabb, *Euphyla trapaquara* Harris.[16] . . . . . 4 feet.

Going north from here the next bluff is known as Brookfield's Bluff, six miles north of Alabama. No fossils were obtained here and the bluff presents a section of:

1. Sand and gravel . . . . . 20 feet.
2. Brown sandstone in heavy bed . . . . . 10 "
3. Clay ironstone . . . . . 1 foot.
4. Laminated dark blue sand and light gray clays with iron pyrites . . . . . 8 feet.
5. Lignite . . . . . 2 inches.
6. Same as No. 4 . . . . . 5 feet.
7. Thin seam of ferruginous sandstone . . . . . 6 inches.
8. Same as No. 4, getting darker in lower portion of the beds and covered in places with a yellow efflorescence of sulphur. Water issuing from these beds is sulphurous and the springs show considerable quantities of hydrogen sulphide to level of river . . . . . 15 feet.

Five miles farther up the river is Hall's Bluff showing a section of:

1. Gravel and sand . . . . . 25 to 30 feet.
2. Fossiliferous sandstone containing *Ostrea sellaformis*, var. *divaricata* Lea, *Cerithium vinctum* Whitf., and casts of others . . . . . 4 "
3. Red sandstone . . . . . 10 "
4. Yellowish-white sand . . . . . 2 "
5. Brown clay with gypsum crystals . . . . . 6 inches.
6. Yellowish-white sand . . . . . 5 feet.
7. Irregular stratum of clay ironstone boulders . . 8 inches.

[16] Harris Mss.

8. Dark greensand, weathering brown, containing fish teeth but not invertebrates . . . . . 6 feet.
9. Brown sand . . . . . 4 "

At Wooter's Bluff, six miles farther north, the beds are also found to be unfossiliferous although the higher grounds lying at some distance away from the river show brown sandstones and altered green sands with few fossils. The section at the bluff appears to be more of a lignitic nature towards the base.

1. Brown and yellowish-brown sand . . . . 10 to 15 feet.
2. Clay ironstone . . . . . 1 to 3 inches.
3. Dark gray micaceous clay, weathering brown on outside . . . . . 20 feet.
4. Clay ironstone . . . . . 1 to 2 inches.
5. Dark blue or bluish-black micaceous clayey sand . . . . . 2 to 6 feet.

About a mile and a half east of this bluff the yellowish clay with limy nodules seen at Elkhart and at Hagues gins occurs immediately below a heavy deposit of yellowish-gray sand.

Crossing the Trinity and going west the "red lands" of Leon County closely correspond in texture and faunal life with the beds of Houston County on the east and the beds found in the northwest corner of Madison County and the Wheelock prairie region. In fact southwest Leon forms but an extension of the Madison and Robertson County beds. A section at the northwest corner of Madison may be taken as a type of these "red lands." This section shows:

1. Brown sand, gravel and conglomerate boulders . 20 feet.
2. Brownish-yellow sand containing *Conus sauridens* Con., *Plenrotoma*, sp., *Ostrea sellaformis*, var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Plicatula filamentosa* Con., *Pseudoliva vetusta* Con., var., *Corbula alabamensis* Lea, *Venericardia planicosta* Lam., *Clavilithes humerosa*, var. *texana* Harris, *Cerithium vinctum* Whitf. and *Mesalia claibornensis* Con. . . . . 2 feet.
3. Fossiliferous sandstone containing a portion of these fossils . . . . . 1 foot.
4. Brown sand . . . . . –

Cedar Creek, near Wheelock lies nine miles west of this point and it was from that place the fossils described by Gabb were obtained. In the list of species described by that writer we find *Belosepia ungula* Gabb, *Murex* (*Odontopolys*) *compsorhytis* Gabb, *Fusus mortonopsis* Gabb, *Neptunea enterogramma* Gabb, *Pleurotoma, Turris kellogii* Gabb, *T. texana* Gabb, *T. retifera* Gabb, *T. nodocarinata* Gabb, *Eucheilodon reticulata* Gabb, *Scobinella crassiplicata* Gabb, *S. leviplicata* Gabb, *Distortio septemdentata* Gabb, *Phos texana* Gabb, *Pseudoliva fusiformis* Con. mss., *P. linosa* Con., mss., *P. carinata* Con. mss., *P. perspectiva* Con. Mss., *Gastridium vetustum* Con., *Agaronia punctulifera* Gabb, *Fasciolaria moorei* Gabb, *Cymbiola texana* Gabb, *Mitra mooreana* Gabb, *M. exilis* Gabb, *Erato semenoides* Gabb, *Neverita arata* Gabb, *Monoptygma crassiplica* Con. Mss., *Architectonica meekana* Gabb, *Spirorbis leptostoma* Swain, *Turritella nasuta* Gabb, *Dentalium minutistriatum* Gabb, *Ditrupa subcoarcuata* Gabb, *Bulla kellogii* Gabb, *Volvula conradiana* Gabb, *Corbula texana* Gabb, *Cibota mississippiensis* Con., *Anomia ephippioides* Gabb.[47]

The whole, or nearly the whole of these species have been obtained by the Texas Survey during the course of the work in that region, and several others have been added to the above list.

The section shown on Cedar Creek and in the immediate vicinity is as follows:

1. Brown prairie sandy soil with occasional blocks or fragments of ferruginous sandstone containing great quantities of *Plicatula filamentosa* Gabb, and *Spirorbis leptostoma* Swain . . . . . 5–15 feet.
2. Brown altered green sand and clay . . . . . 4 "
3. Thin seam of ferruginous sandstone . . . . . 1 foot.

Nos. 2 and 3 contain quite an extensive fauna comprising *Actæon punctatus* Lea, *Bulimella kellogii* Gabb, *Terebra houstonia* n. sp., Harris, *Conus sauridens* Conrad, *Pleurotoma* (*Surcula*) *gabbii* Con., *Pl.*—, *Pl.* (*Cochlespira*) *engonata* Gabb, *Pl. bella* Con., *Pl.* (*Surcula*) *moorei* var., Gabb, *Pl.* (*Drillia*) *nodocarinata* Gabb, *Pl. terebriformis* Mr., n. sp., *Pl.* (*Drillia*) *texacona* Harris, *Pl.* (*Borsonia*) *plenta* Harris, *Cancellaria tortiplica* Con., *Ancilla* (*Olivula*) *staminea* Con., *Pseudoliva vetusta*, var. *picta*, *P. vetusta* Con., var.

[47] Journal Academy of Nat. Sci. of Phila., Second Series, Vol. 4, pp. 376–389 and plates 67 and 69.

P. vetusta, var. *fusiformis* Lea, *Ostrea alabamensis* Lea, *O. sellaeformis*, var. *divarieata* Lea, *Anomia ephippioides* Gabb, *Plicatula filamentosa* Conrad, *Byssoarca cueullοides* Con., *Trigonarca pulchra* Gabb, *T. corbuloides* Con., *Nucula magnifica* Con., *Leda opulenta* Con., *Yoldia claibornensis* Conrad, *Marginella semen* Lea, *Volutilithes petrosa* Con., *V. precursor* Dall, *V. dalli* Harris, n. sp., *Turricula polita* Gabb, *Latirus moorei* Gabb, *Cornulina armigera* Gabb, *Pteropsis conradi* Dana, *Corbula aldrichi*, var. *smithvillensis* Harris, *C. texana* Gabb, *C. alabamensis* Lea, *Dentalium minutistriatum* Gabb, *Dentalium minutistriatum* Gabb, var. *dumblei*, n. var., *Venericardia planicosta* Lam, *Cytherea tornadonis* Harris, *C. bastropensis* Harris, *Fusus mortoni* var. *mortonopsis* Gabb, *Pleurotoma texana* Gabb var., *Distortio septemdentata* Gabb, *Tuba antignata*, var. *texana* n. var., *Solarium scrobiculatum* Con., *S. vespertinum* Gabb, *Natica arata* Gabb, *N. limula* Con., *N. semilunata*, var. *janthinops* n. var., *Sigaretus inconstans* Ald., *S. declivis* Con., *Pyrula* (*Fusoficula*) Ald., *P.* (*Fusoficula*) *penita* Con., var., *Mesalia claibornensis* Con., *Turritella nasuta* Gabb, *T. dumblei* Harris n. sp., *Aturia*, near *zic zac. Belosepia magnla* Gabb, *Flabellum* sp., *Turbinolia pharetra* Lea and *Lunulites* sp.

4.	Pale to purplish-pink clay found 200 yards farther down Cedar Creek than No. 3. Very few fossils found in this bed . . .	4 to 6 feet.
5.	Dark grayish-green sand containing, in addition to the greater number of the fossils found in No. 2, the following: *Pleurotoma childreni*, var. *bilota* Harris, *Cancellaria panones*, var. *juniperа* Harris, *Cancellaria gemmata* Con., *Volutilithes petrosa*, var. *indenta* Con., *Cadulus sub-coarcuatus* Gabb, *Chrysodomus enterogramma* Gabb and *Solarium acutum*, var. *meekanum* Gabb	4 "
6.	Green sand with laminæ of clay containing nearly the same fauna as in Nos. 3 and 5 with *Actæon punctatus* Lea and *Pl. retifera* Gabb,[48] additional	4 to 6 "
7.	Dark brown and purplish-brown sand and	

[48] Harris Mss.

clay, laminated with fossils in sand, to bed of creek . . . . . 2 feet.

The next section west of this is on Campbell's Creek, near Dunn's ranch and about six miles west of Wheelock. This shows:

1. Black soil . . . . . 2 to 4 feet.
2. Brown sand with calcareous material . . . 4 to 8 "
3. Ferruginous brown sandstone and sands, altered green sands with *Conus sauridens* Con., *Pleurotoma (Surcula) gabbii* Con., *Pl. (Drillia) nodocarinata* Gabb, *Pl. (Borsonia) plenta* Harris, *Ancilla (Olivula) staminea* Con., *Ostrea sellæformis*, var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Nucula magnifica* Con., *Pseudoliva vetusta* Con., var., *P. vetusta*, var. *fusiformis* Lea, *Volutilithes petrosa*, var. *indenta* Con., *V. precursor* Dall, *Latirus moorei* Gabb, *Corbula texana* Gabb, *Venericardia planicosta* Lam., *Fusus mortoni*, var. *mortonopsis* Gabb, *Phos texana* Gabb, var., *Distortio septemdentata* Gabb, *Sigaretus declivis* Con., *Mesalia elaibornensis* Con., *Turritella nasuta* Gabb, *Turritella dumblei* Harris n. sp., *Belosepia ungula* Gabb . . . . . 4 feet.
4. Black laminated clay, enclosing *Conus sauridens* Con., *Pleurotoma (Surcula) gabbii* Con., *Pl. childreni*, var. *bilota* Harris, *Pl. (Drillia) nodocarinata* Gabb, *Pl. (Borsonia) plenta* Harris, *Ostrea sellæformis*, var. *divaricata* Lea, *Pseudoliva vetusta* Con. var., *Volutilithes petrosa* Con., *Latirus moorei* Gabb, *Venericardia planicosta* Lam., *Cytherea tornadonis* Harris, *Chrysodomus enterogramma* Gabb and *Natica arata* Gabb . . . . . 2 feet.
5. Indurated green sand with *Occulina*, *Turbinolia pharetra* and *Endopachys maclurei* corals and in addition to the fossils found

	in No. 4 *Ancilla ancillops* Heilpr., *Byssoarca cucullοides* Con., *Pseudoliva vetusta* var. *fusiformis* Lea, *Volutilithes precursor* Dall., *Cornulina armigera* Con., *Corbula aldrichi*, var. *smithvillensis* Harris, *C. texana* Gabb, *Dentalium minutistriatum* Gabb, *Fusus mortoni*, var. *mortonopsis* Gabb, *Phos texana* Gabb, *Distortio septemdentata* Gabb, *Solarium scrobiculatum* Con., *S. acutum*, var. *meekanum* Gabb, *Pyrula* (*Fusoficula*) *texana* Ald., *Mesalia claibornensis* Con., *Turritella nasuta* Gabb-[49] . .	1 foot.
6.	Laminated fossiliferous blue clay	10 feet.
7.	Alternate strata of yellowish sand and blue clay, clay 6 inches and sand from 4 to 8 inches thick	4 "
8.	Brown sand	1½ "

The connection between these beds will be readily understood when it is stated that at least 30 of the 38 species found at Campbell's Creek are common to Wheelock and the exact stratigraphic position of the two sections can be seen in a section on the Town branch, south of the town of Wheelock and intermediate between the Cedar Creek and Campbell's Creek sections. Out of some 36 species obtained 19 are common to Campbell's Creek, 26 to Cedar Creek and the following 10 do not occur at either: *Pleurotoma* (*Drillia*) *texana* Gabb, *Pl.* (*Drillia*) *plebοides* Harris, *Pl.* (*Mangelia*) *infans* var. Mr., *Pl.* (*Scobinella*) *crassiplicata* Gabb, *Turricula* (*Conomitra*) *texana* Harris, *Terebra amœna* Con., *Periploma collardi* Harris n. sp., *Clavilithes humerosa*, var. *texana* Harris, *Clavilithes* (*Papillina*) *dumosa*, var. *trapaquara* Harris, and *Caricella subangulata*, var. *cherokeensis* Harris.[50]

The section shown at this place is:

1.	Black surface soil	1 to 3 feet.
2.	Dark-brown gypseous clay, base of the Yegua stage	1½ "
3.	Brown fossiliferous sandstone and brown clay	

[49] Harris Mss.

[50] Harris Mss.

interstratified and containing the above fossils . . . . . 3 "

4. Blue laminated clay in which no fossils were found, to bed of stream . . . . . 2 "

Small sections of a similar character occur on Elm Creek, near Burckley Station and on the Wilson Reid Headright, both lying between Campbell's Creek and the Brazos River.

Along the Brazos we have probably the most important and most complete section of these beds. To the south we find them passing beneath the Yegua clays about 500 yards south of the mouth of the Little Brazos. Thence throughout a succession of bluffs we can trace the Marine beds northward to their contact with the underlying lignitic a short distance north of International Railway bridge, a direct distance of twelve miles. The section showing the contact between the Yegua clays and the Marine beds has already been given, and the next section, that on the Little Brazos, near the iron bridge, on the Moseley's Ferry and Bryan road shows:

1. Chocolate brown clayey soil, river deposits . 10 to 15 feet.
2. Gravel . . . . . 2 to 4 "
3. Laminated unfossiliferous clay . . . . . 4 "
4. Pale blue unfossiliferous clay . . . . . 1 to 3 "
5. Thinly laminated blue to black colored clay containing *Terebra houstonia*, Harris, *Terebra texagyra* var. Harris, *Conus sauridens* Con., *Pleurotoma* ; *Pleurotoma (Surcula) gabbii* Con., *Levifusus trabeatoides* Harris, *Pl. (Surcula) moorei*, Gabb, *Pl. (Drillia) nodocarinata* Gabb, *Pl. terebraeformis* Mr., *Pl. (Mangelia) insignifica* Heilprin, *Pl. (Drillia) texacona* Harris, *Pl. (Drillia) penrosei* Harris, *Ancilla (Olivula) staminea* Conrad, *Ancilla ancillops* Heilprin, *Nucula magnifica* Con., *Leda opulenta* Con., *Pseudoliva vetusta* var., *P. vetusta* var. *fusiformis* Con., *Volutilithes petrosa* Con., *V. precursor* Dall, *Latirus moorei* Gabb, *Tellina mooreana* Gabb, *Dentalium*

minutistriatum var. *dumblei* Harris, n. var. *Venericardia planicosta* Lam., *Distortio septemdentata* Gabb, *Solarium alveatum* Con., *S. vespertinum* Gabb, *Phos texana* Gabb, var. *Chrysodomus parbrazana* Harris, n. sp., *Natica arata* Gabb, *N. semilunata* var. *janthinops* Harris, *Pyrula (Fusofienla) texana* Ald., *Turritella nasuta* Gabb, *Turritella dumblei* Harris, n. sp.[51]

6. Fossiliferous iron ore . . . . . 1 foot.

7. Fossiliferous green clay containing most of the fossils found in No. 5 with *Atys. Bulimella kellogii* Gabb, *Pleurotoma (Cochlespira) engonata*, Con., *Pl. childreni* Lea, var. *bilota* Harris, *Pl. retifera Pl. (Mangelia) infans* var. Mr., *Cancillaria tortiplica* Con., *C. panonis* var. *smithvillensis* Harris, *Byssoarca cucullioides* Con., *Turricula polita* Gabb, *Corbula alabamensis* Lea, *Cadulus sub-coarcnatus* Gabb, *Pyramidella prexilis* Con., var., *Solarium acutum* var. *meekanum* Harris, *Meslia Claibornensis* Con., *Terebra texagyra* n. sp. var. Harris.[52]

The next section is shown at Moseley's Ferry on the Brazos. This is the section referred to by Dr. Ferdinand Roemur as being visited by him in 1847 and which he characterized as "consisting of alternate strata of brown ferruginous sandstones and of dark colored plastic clays, both teeming with fossils."[22] The bluff here extends along the river a distance of about 1,500 feet and is from 25 to 30 feet high. With the exception of the upper 15 feet of brown sand it is fossiliferous throughout. The fossils are very well preserved, exceedingly plentiful and easily obtained. The dip of the beds as shown in this bluff is between 50 and 55 feet per mile, but it may be said that throughout this region as well as other portions of the older Eocene reliable dips are very hard to obtain.

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[51] Harris MSS.
[52] Am. J. of Sci. Vol. vi, Second series, 1848, p. 23.

Section at Moseley's Ferry, Brazos River :—

1. Brownish yellow surface loam . . . . . 15 feet.
2. Thin stratum of fossiliferous iron ore in boulder form . . . . . 6 inches.
3. Blue laminated fossiliferous clay. . . . . 3 feet.
4. Fossiliferous iron ore, running under the river about 100 yards below the ferry . . . . . 2 "

Nos. 2, 3 and 4 contain an extensive fauna, comprising *Levifusus trabeatoides* Harris, n. sp., *Conus sauridens* Con., in great numbers, *Pleurotoma (Surcula) gabbii* Con., *Pl. (Cochlespira) engonata* Con., *Pl. (Drillia) nodocarinata* Gabb, *Pl. terebriformis* Mr., *Pl. (Borsonia) plenta* Harris, *Ostrea sellaformis* var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Byssoarea cuculloides* Lea, *Pseudoliva vetusta* var. *Volutilithes petrosa* Con., *Volutilithes precursor* Dall., *Turricula polita* Gabb, *Latirus moorei* Gabb, *Corbula texana* Gabb, *Dentalium minutistriatum* Gabb, *Dentalium minutistriatum* var. *dumblei* new variety, *Venericardia planicosta* Lam., *Cytherea texacola* Harris, *Cytherea tornadonis* Harris, *Chrysodomus enterogramma* Gabb, *Phos texana* Gabb, var., *Distortio septemdentata* Gabb, *Tuba antiquata* var., *antiqua* new var., *Solarium acutum* var. *Meekanum* Gabb, *Sigaretus declivis* Con., *Mesalia claibornensis* Con., *Turritella nasuta* Con., *T. dumblei* Harris, n. sp., *Pyrula (Fusoficula) texana* Ald., and several corals.[53]

5. Laminated fossiliferous blue clay containing *Conus sauridens* Con., *Pleurotoma (Surcula) gabbii* Con., *Pl. (Cochlespira) engonata* Con., *Pl. (Borsonia) plenta* Harris, *Pl. (Surcula) moorei* var. *Levifusus trabeatoides* Harris n. sp., *Ancilla (Olivula) staminea* Con., *Pseudoliva vetusta* var., *Volutilithes petrosa* Con., *Dentalium minutistriatum* Gabb, *Venericardia planicosta* Lam., *Leda opulenta* Con., *Cytherea texacola* Harris, *Distortio septemdentata* Gabb, *Mesalia claiborneusis* Con., *Turritella nasuta* Fabb and *Belosepia ungula* Gabb . . . . . 6 feet.

[53] Numbers 2, 3 and 4 are marked A in Mr. Harris' lists; No. 5, B; Nos. 6, 7 and 8, C; No. 9, D; No. 10, E; Nos. 11, 12 and 13, F.

6. Fossiliferous iron ore . . . . . 2 feet.
7. Altered fossiliferous green sand found at north end of bluff . . . . . 10 "
8. Fossiliferous iron ore . . . . . 2 "

Nos. 6, 7 and 8 contain *Conus sauridens* Con., *Pleurotoma* (*Surcula*) *gabbii* Con., *Pl.* (*Drillia*) *nodocarinata* Gabb, *Pl.* (*Borsonia*) *plenta* Harris, *Levifusus trabeatoides* Harris n. sp., *Anomia ephippioides* Gabb, *Pseudoliva vetusta* Con. var., *Latirus moorei* Gabb, *Venericardia planicosta* Lam., *Distortio septemdentata* Gabb, *Turritella dumblei* Harris n. sp., *Byssoarca cucullaides* Con., *Solarium acutum*, var. *meekanum* Gabb.

9. Green sand, dark green near ferry, but altering to a brown near north end, and merging into No. 7, measuring at ferry . 5 feet.

This bed contains *Conus sauridens* Con., *Pleurotoma* (*Surcula*) *gabbii* Con., *Ancilla* (*Olivula*) *staminea* Con., *Ostrea sellaformis*, var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Pseudoliva vetusta* Con., var., *P. vetusta*, var. *carinata* Con., *Pteropsis conradi* Dana, *Corbula texana* Gabb, *Venericardia planicosta* Lam., *Cytherea texacola* Harris, *Fusus mortoni*, var. *mortonopsis* Gabb, *Phos texana* Gabb, var. *Distortio septemdentata* Gabb, *Turritella nasuta* Gabb, and *Tenuiscola trapaquara* Harris n. sp.,[54] *Turbinolia pharetra* Lea, *Endopachys maclurei* Lea and other corals.

10. Thinly laminated blue clay, changing into brown near top, and weathering to a light blue toward the bottom; the upper brown portion contains fossils similar to those in No. 9, and the lower blue contains occasional crystals of selenite . . . . . 15 feet.
11. Dark, almost black, fossiliferous sandy clay . 10 "
12. Thin seam of black clayey sand, jointed and stained brown along joints and on outside, apparently unfossiliferous . . . . . 1 foot.
13. Same as No. 11, extending into river and forming a ledge in bottom of river . . . 14 feet.

Nos. 11 and 13 contain *Pleurotoma childreni* Lea, var. *bilota* Harris, *Yoldia claibornensis* Ald., *Pseudoliva vetusta* Con., var.,

[54] Harris Mss.

Tellina mooreana Gabb, *Venericardia planicosta* Lam., *Cytherea bastropensis* Harris, *Turritella nasuta* Gabb.

The section next seen is at Niblett shoals, about a mile and a half north of Mosley's Ferry. This section shows a decided change in which we find from 12 to 14 feet of lignitic shales, sands and lignites lying beneath in 20 feet of river loam.

The next section is at Collard's Ferry, four miles north of Mosley's.

This section has been described by Dr. Penrose as the Burleson shell bluff,[55] there being no ferry at this place when visited by Penrose. The section here given is essentially the same as given by him, the only difference being the division of the upper twenty feet of fossiliferous green sand. The section shows:

1.	Brown sand	10 feet.
2.	Indurated brown altered green sand . . .	8 inches.
3.	Brownish-green altered green sand	4 to 6 feet.
4.	Grayish-green sand	10 to 15 feet.

Nos. 3 and 4 of the section contain *Pleurotoma* (*Surcula*) *gabbii* Con., *Pl. childreni* Lea, var. *bilota* Harris, *Cancellaria minuta* Harris, *Olivella bombylis*, var. *burlesonia* Harris n. var., *Ostrea sellaformis*, var. *divaricata* Lea, *Plicatula filamentosa* Conrad, *Pecten deshayesii* Lea, *Pinna* sp., *Byssoarca cuculloides* Conrad, *Leda opulenta* Con., *Pseudoliva vetusta* Con., variety *Volutilithes petrosa*, var. *indenta* Con., *Lapparia pactilis*, var. *mooreana* Gabb, *Latirus moorei* Gabb, *Corbula aldrichi*, var. *smithvillensis* Harris, *Dentalium minutistriatum* Gabb, *D. minutistriatum*, var. *dumblei* Harris n. var., *Venericardia rotunda* Lea, *V. alticostata*, var. *perantiqua* Con., *V. planicosta* Lam., *Cytherea* sp., *C. texacola* Harris, *C. bastropensis* Harris, *Clavilithes* (*Papillina*) *dumosa*, var. *trapaquara* Harris, *Fusus mortoni*, var. *mortonopsis* Gabb, *Clavilithes penrosei* Heilprin, *C. humerosa*, var. *texana* Harris, *Pleurotoma* (*Clathurella*) *fannæ* Harris n. sp., *Solarium scrobiculatum* Con., *S. alveatum* Con., *Natica semilunata*, var. *janthinops* Harris n. var., *N. newtonensis* Ald., *Sigaretus declivis* Con., *Pyrula* (*Fusoficula*) *penita* Con. var., *Rimella texana* Harris n. sp., *R. texana*, var. *plana* Harris n. var., *Calyptrophorus velatus* Conrad, *Turritella*, sp., *Belosepia ungula* Gabb, *Trochita*, sp. and corals *Turbinolia pharetra* Lea.

[55] First Annual Report Geol. Survey of Texas, 1889, p. 27.

5. Dark blue laminated clay . . . . . 6 to 8 feet
6. Brown coal in river . . . . . 4 feet

This bluff extends up the river for nearly a mile and is from twenty to twenty-five feet high. The fossils are plentiful and well preserved, although not so easily obtained as at Moseley's Ferry. *Pecten deshayesii* is particularly plentiful, in some portions forming solid masses from four to six inches thick for considerable distances.

From here to the base of the beds at the railway bridge no fossils have been obtained.

The similarity of the structure of these beds and their contained fauna from the Angelina River on the east to the Brazos on the west, as well as the several isolated exposures lying in the counties east of the former, mark a continuity extending clear across east Texas. These beds are also well marked to the west of the Brazos and at Smithville, on the Colorado, we find another great assemblage of fossils, the greater number of which are identical with those found on the Brazos and Wheelock. It may, however, be remarked that so far as numbers of several of the specimens are concerned many of the species show considerable differences. Thus, *Conus sauridens*, although scarcely represented at any locality east of the Trinity becomes very prolific at Moseley's Ferry, on the Brazos. The same may also be said of *Pecten deshayesii*, which, though numerous at Collier's Ferry on that river is scarce in the east. On the other hand *Plicatula filamentosa* and *Spirorbis leptostoma* are abundant in Hurricane Bayou and at Alabama Bluff, although extremely few of these have been obtained anywhere else.

The correlation of these beds with the Lisbon stage of the Lower Claiborne of the Alabama section appears to rest upon several grounds. First, their stratigraphic position. In both States they rest upon the lignitic. It is true the Buhrstone of the Alabama section intervening between the Lisbon and Lignitic is absent in Texas. Both comprise a series of highly fossiliferous sandy and clayey strata with glauconitic green sand and sands containing streaks and nodules of calcareous matter, much of which is badly weathered. Some of the beds are indurated into hard ledges of brown or yellow sandstones, but brownish-greenish and bluish-green soft sands and plastic clays form the great bulk of the deposits. The presence of small beds and deposits of lignite and lignitic strata at irregular intervals in the Texas beds marks the most prominent dif-

ference between these beds and Lower Claiborne of Alabama. The presence of these lignitic strata in the Texas beds and their absence in Alabama appears to show a difference in the conditions of deposition in the two localities. The lignitic is essentially a marsh production, while the others belong to a coastal marine, or at least comparatively shallow sea, and the occurrence of the two in connection with each other would lead to the inference that while a steady marine condition of affairs continued in Alabama, the Texas regions were subjected at irregular intervals to slight oscillations during which the alternate conditions of marsh and sea deposition took place and the presence of marine fossils in the lignitic beds appears to show that these marshes were also subjected to marine influences. The third reason for considering these beds as being synchronous with the Lisbon beds and partly with the green sands of the lower or lignitic beds is their contained fauna. Heilprin states that of some one hundred and forty-five species determined by him about sixty-one, or upwards of forty per cent. are also members of the Claiborne fauna of Alabama, and a few others also occur in some of the older deposits of Alabama. He considers these beds to belong to the Claibornian or typical Middle Eocene of the gulf slope.[56] After the examination of a much more extensive fauna obtained from these beds Mr. Harris arrives at the conclusion that they belong to the Lisbon sub-stage of the Lower Claiborne.[57] Gabb also arrives at the same conclusion in regard to the fossils found at Wheelock and in Caldwell county, as he says "they are all from a deposit apparently synchronous with that at Claiborne, Alabama; one-third of the species found in the Texan beds being specifically identical with those found in Alabama."[58]

The identity of the fossils found in the Yegua clays and Fayette sands with those of the Marine beds appears to place these two stages in the same age.

These beds occupy a wide area of country lying immediately north of the Yegua clays which form their southern boundary, and their northern line may approximately be drawn from the Sabine River a short distance north of Sabine Town in a generally northwestern direction to the middle of the eastern line of Smith County. Turn-

[56] Proceedings of the Academy of Nat. Sci., Phila., Oct., 1890, p. 393.
[57] Harris' Monograph of the Texas Tertiary Fossils MSS.
[58] Journal of the Acad. of Nat. Sci., Second Series, Vol. 4, p. 376.

ing west the line continues in a west by south direction to near Brownsboro, in Henderson, and thence south to the Trinity near the south line of Anderson, and from there in a southwesterly direction to the Brazos. Throughout the northeastern portion of the state isolated hills covered by deposits of the same age occur in some of the counties. These, however, are usually unfossiliferous and of no great extent.[59] The main body of the beds occupies a position in the form of an inverted V, being widest at its apex, where a line drawn across them from Bullard through Jacksonville, Rusk and Alto measures over forty miles. From this line they gradually narrow both to the west and east until on the Brazos the width does not exceed thirteen miles, and on the Sabine not more than seven or eight.

The dip of these beds appears to be in an inverse ratio to the width—that is to say it is greater on the Brazos than farther east, and gradually becomes less as we approach the Sabine. While the great or general dip of the whole of these deposits is toward the gulf they have apparently been subjected to pressure from the south or southeast as in many places slight waving or undulations occur that give the beds the appearance of dipping toward the northwest in many places. These undulations are greater in the basal division or "Mount Selman series," and pass into the underlying lignitic. A very good type of this formation may be seen in Mount Selman itself as that mountain forms the bottom of a synclinal trough. They do not appear in the Yegua clays or succeeding deposits, and whether they affect the cretaceous beds or not is not known with any degree of certainty, although it is generally assumed that they do to some small extent.

The topography of the country occupied by the Marine beds may be described as an elevated plateau rising abruptly from the plane of the surrounding beds to an average elevation of five hundred feet above sea level, although some of the higher "mountains" reach elevations of over seven hundred feet. This plateau is so intersected by the different rivers flowing across it and their subsidiary drainage channels that it presents a much broken surface showing as narrow-topped, steep-sided, ridges in many places and wide flat-topped hills in others. This variation is chiefly due to the covering of the different localities. When sand forms the prevailing material the ridges are narrow and the reverse is the rule where we find the iron ore

[59] Science, Vol. XXIII, No. 571, pp. 22–25.

deposits overlying. Wide "bottoms" and "second bottoms" land fringe the margins of the main streams and many of the larger creeks, and the whole flow at very low levels, often one hundred to one hundred and fifty feet below the summit making deep V-shaped channels where no bottom lands exist. In many places, particularly in the sandy beds erosion is very rapid and many of the eastern water courses have reached and are now flowing in the underlying lignitic beds.

Throughout the higher grounds the surface is generally covered with light gray or yellow sand derived from the disintegration of the underlying beds through leaching or otherwise, and in places a light scattering deposit of yellow stained quartz gravel occurs. These upper beds support a heavy cover of short leaved pine, oak and hickory in portions of the region and wide areas in several of the counties towards the middle of the district are covered with heavy beds of laminated iron ore. These overlying sands and ores have been ascribed to the quaternary by Mr. L. C. Johnson,[60] but the occurrence of fossils of the same age as the underlying beds within them place them in the Marine beds and consequently of Eocene age.

Lignitic Beds.

The northern boundary of the Marine beds marks the southern limit of an another series of deposits totally differing from these in every respect. In physical structure, materials and mode of deposition these lower beds have nothing in common with the overlying Marine beds. They form the lowest portion of Penrose's Timber Belt or Sabine river beds and are known as the Lignitic stage of the Texas Eocene. These beds comprise a series of sands, clays and lignites and have an aggregate thickness of over 1,200 feet.

The sands are variously colored, being white, yellow, brown, red, gray or blue, with occasional thin beds of black, often shading into one another in endless variety, and, with the exception of the dark blue or black and occasionally white beds, present no uniformity of coloration for any distance. In structure they are mostly coarse-grained with irregular deposits of fine-grained silty sand, laminated or thinly stratified, massive, cross-bedded and frequently interlaminated with clay.

The clays occur interstratified and interlaminated, or as irregular

[60] Iron Ores of East Texas and Northern Louisiana, L. C. Johnson, p. 25.

deposits, with the sands, and in such positions are usually laminated. Massive and stratified beds also occur in many portions of the area, sometimes nearly free from sand, but the greater portion occur as sandy or micaceous clays. Plastic potter's clay and refractory clays occur in abundance. In color they are generally dark blue, gray and black, although deposits of red, brown and yellow clay occur and frequently thin beds of white clay are found among the upper members of the series.

The lignites belonging to this stage and from which these beds derive their name occur widely spread throughout the whole area; they lie in beds of varying thicknesses, from two to four feet being most common, although six, nine and ten feet deposits are by no means of rare occurrence. Beds of even greater thickness have been reported as being found in well-borings. The actual number of lignite beds existing in these deposits is not known. Six have been recorded as underlying each other at distances varying from two to one hundred and twenty feet apart.

Silicious and calcareous sandstones and limestones occur at different portions of the area occupied by these beds, but the glauconitic greensand marls so conspicuous in the Alabama lignitic are everywhere absent from the Texas beds.

The lignitic beds have been divided into two divisions—an upper and lower—distinguished chiefly by their structure and composition. The upper or Queen City beds, so called from their typical development near that place in Cass county, comprise a series of laminated or thinly stratified white and red sands and sandy clays frequently merging into one another and forming a mottled sandy clay or clayey sand. The laminæ generally do not exceed one-fourth to half inch but the white sandy clay frequently expands to six or more feet filling pockets or depressions in the wavy laminated deposits. In this pocket-form these clays become less sandy and more aluminous than when occurring in thin seams. The section at Queen City shows these beds to have a thickness of 65 feet. This section is :[61]

1.	Gravelly ore, and broken pieces of nodular ore, sandstone and sand	5 feet.
2.	Laminated ore and sand in thin strata	4 "

[61] Second Annual Report Geol. Survey of Texas 1890, p. 72.

3.	Stratified white and red sand with white sandy clay (Queen City beds)	65 feet.
4.	Brown sand and clay	25 "
5.	Lignite	1½ "

These beds have never been outlined but are known to occur at various localities in Cass county. In Marion county, near Jefferson, and in Harrison county these beds appear at various places immediately underlying the yellowish brown sandstone here forming the base of the Marine beds. The same beds are also found at Willow Switch near Longview and Gladewater in Gregg Co.,, and also occur near Tyler in Smith county and at Wilkins' Mill in Upshur Co.

These beds are unfossiliferous throughout. Not the slightest trace of a fossil of any kind has ever been found in them and they do not carry lignite. They are, however, readily recognized, and whenever present, are conspicuous from their clear, distinct, banded appearance lying between the brown and brownish-yellow beds above and below them. They have been correlated with the Carrizo sandstones of the Tertiary west of the Brazos.[62]

The lower lignitic deposits are very different from the Queen City beds in many respects. These contain the dark blue, gray, black, brown and yellow clays and sands, sandstones and lignites so characteristic of the lignite group everywhere, and form by far the most extensive deposits belonging to this stage of the Eocene.

In Bowie county, in the extreme northeastern portion of the state, lignitic clays and lignites occur; in Cass county the same deposits show the typical structure at many places. A section at the Alamo mine, on Sulphur Fork, shows:

1.	Sand and clay	26 feet.
2.	Gray clay	23 "
3.	Lignite	1 ft. 8 inches.
4.	Gray sand	2 feet.
5.	Hard slaty clay	9 "
6.	Lignite	4 feet +

In Marion county the enormous thickness of these beds is seen in the artesian boring made for water at Jefferson. Here the drill passed through alternate strata of sands, clays and lignites to a depth

[62] Dumble, Journal of Geology, Sept., 1894.

of 802 feet, but without reaching their base. Three heavy beds of lignite and a number of smaller ones are said to have been passed through in the boring. In Harrison and southward through Panola, Shelby and eastern San Augustine we find these deposits underlying the remnantal Marine beds and passing under the main body of these at many places. Everywhere throughout the Sabine Valley sections showing lignites may be seen. A section at Robertson's ford shows:

1.	Gray sand	1 foot.
2.	Mottled brown, blue and yellow clay	45 feet.
3.	Lignite	6 "
4.	Dark blue sandy clay to water	3 "

Near Carter's Ferry, on the same river, we find a deposit of lignite six feet thick containing trunks of trees from sixteen to twenty feet in length and eighteen to twenty inches in diameter, partly silicified and partly lignitized. These are exposed at low water. Near Logansport a section of the river bluff is reported to give:[63]

1.	Gray sandy soil	2 feet.
2.	Mottled yellow and gray clay	10 "
3.	Yellow and blue clay	4 "
4.	Nodular iron ore, nonconformable	1 foot.
5.	Sandy clay.	3 feet.
6.	Iron sandstone, irregular	1 foot.
7.	Lignitic shales to water	2 feet.

Coming westward, the same lignitic sands and clays with more or less lignite occur in Smith, Wood, Henderson, Freestone, Limestone, Leon and Robertson counties. Sections typical of the whole region can be obtained almost anywhere. The section of these beds as shown on the Brazos gives:

I. Calvert Bluff Section:—

Recent.	1.	Brown loamy clay	4 feet.
	2.	Light brown sand	7 "
	3.	Brown sand and gravel	1½ "
	4.	Gray sand	0 to 3 "
	5.	Brown coal	12 "
	6.	Dark blue clay	3 "
	7.	Brown coal	3 "

[63] Second Annual Report Geol. Survey of Texas, 1890, p. 252.

Lignitic.

8.	Dark blue clay same as No. 6	6 feet.
9.	Brown coal	3 to 4 "
10.	Dark grayish blue sand	15 "
11.	Thin stratum of calcareous sandstone . . .	½ foot.
12.	Dark gray sand similar to No. 10	2 feet.
13.	Brown coal, poor quality	2 to 6 inches.
14.	Dark gray sand similar to No. 10	8 feet.
15.	Gray calcareous sandstone	1 foot.
16.	Dark bluish gray sand with iron pyrites . .	8 feet.
17.	Boulders of clay ironstone and gray calcareous sandstones with irony nodules and thin seams of ferruginous sandstones with dicotyledonous leaves	2 feet.
18.	Gray sandstone	1½ "
19.	Laminated bluish gray sand to water	2 "

A little over a mile farther up the river we find section II at Bee shoals showing the following beds belonging to the lignitic. Nos. 1, 2 and 3 of the section are omitted as they belong to the more recent and river alluvium:

II. Section at Bee Shoals:—

4.	Black or dark blue clay	5 feet.
5.	Broken seams of brown coal	½ to 3 "
6.	Black clay same as No. 4	5 "
7.	Dark bluish-gray sandstone weathering on outside to a brown containing broken plant remains	1½ to 6 feet.
8.	Clay similar to Nos. 4 and 6	4 "
9.	Thin stratum of gray calcareous sandstone .	4 to 6 inches.
10.	Gray sand laminated and containing thin layers of dark clay	10 feet.
11.	Rounded waterworn boulders with calcite streaks	1 foot.
12.	Gray sand with pyrites	0 to 5 feet.

From this point to the base of the lignitic beds near the mouth of Pond Creek the beds comprise a series of gray sands interstratified with gray sandstones. These sands and sandstones cannot be less than 300 feet in thickness. A section at Gibson's gin near Calvert shows them to be at least 265 feet. The following is the section :

1.	Surface soil and gray and brown sand . . .	25 feet.
2.	Alternate strata of blue clay and calcareous sandstone	42 "
3.	Brown coal	2 "
4.	Bluish-gray sand, blue clay and calcareous sandstones	46 "
5.	Brown coal	1½ "
6.	Bluish gray sand	23½ "
7.	Brown coal	5 "
8.	Blue sands and sandstones	55 feet.
9.	Brown coal	2 "
10.	Red clay	8 "
11.	Bluish-gray calcareous sandstones and blue clay	22 "
12.	Brown coal	2 "
13.	Blue sand	76 "
14.	Brown coal	10 "
15.	Blue sand with thin seams of sandstone . .	265 "

A well at Franklin, the county seat of Robertson, obtains its water supply from these beds and is 1,208 feet deep. This boring is wholly in lignitic strata and chiefly in the lower division.

While there is no doubt whatever as to the stratigraphic position of the Texas Lignitic corresponding closely to that of the Lignitic of Alabama, both occupying positions beneath the Lower Claiborne and overlying the uppermost beds of the Cretaceous, there are many conditions of dissimilarity between them that mark the deposition of each to have been associated with and made under widely different circumstances. Nor do these Texas beds altogether correspond with the Lignitic of Mississippi, Arkansas or Louisiana, although in the case of the two last named States the beds found in the southwestern portion of Arkansas and in the northwestern corner of Louisiana are similar in every respect to those of that portion of Texas adjoining them.

In Alabama the greater portion of this sub-division is made up of laminated clays and laminated and cross-bedded sands of a prevailing gray color, except immediately below the Buhrstone, where for 200 feet or more they are of dark brown, often purplish colors. With the above mentioned laminated clays and sands are interstratified

several beds of lignite and several beds holding marine fossils and usually characterized by the presence of glauconite or greensand.[64]

According to Smith and Johnson the lignites appear to be more numerous and thicker toward the west, while eastward of the Alabama River they become, as a rule, inconspicuous and possess no very well marked characters by which they may be distinguished from one another. On the other hand the Marine beds retain their characteristic features and peculiar association of fossils, are easily recognizable and may be followed with the greatest ease.

In Mississippi the Lignitic comprises a series of lignitiferous strata with interstratified beds of brown, yellow and gray sands and clays containing marine fossils and plant remains.[65]

These beds also occur in Southern Arkansas at the Ouachita Coal-mining Company's mines at Lester, about seven miles north of Camden. Here the section shows heavy beds of dark blue clay enclosing a deposit of lignite from 6 to 10 feet thick. The higher hills in this neighborhood are capped with the red and white sands and clays typical of the Queen City beds of Texas, and as already stated the southwestern portion of Miller county belongs geologically to the Texas beds.

Hill describes the basal or lignitic strata of southwestern Arkansas under the local names of the Camden series and Cleveland county red lands. The former, he says, "is an extensive shallow water, marine formation of stratified, micaceous, non-indurated alternating laminæ of sands and clay shales, sandy shales, thin sandstones (quartzites), etc.,"[66] and considers them a continuation of similar stratigraphic conditions from other counties of Louisiana, Arkansas and Texas from the southward. His Cleveland "red lands" constitute a fossiliferous horizon at or near the top of the Camden series, and consists of the characteristic sediments of that series, but is accompanied by extensive deposits of marine shells and greensand,[67] and are identical with the iron bearing red lands of Rusk, Cherokee and other counties in northeast Texas.

A personal examination of much of the Tertiary areas of Arkansas leads me to very different conclusions from those drawn by Prof.

[64] Bull. U. S. G. S., 43, p. 39.
[65] Bull. U. S. G. S., 83, p. 67.
[66] Vol. II. Ann. Rep. Geol. Survey of Ark., 1888, p. 49.
[67] Geol. Survey of Ark., Vol. II. of 1888, p. 58.

Hill. The basal Tertiary of the region while in its principal features undoubtedly lignitic and in places correspond to the Texas beds, his Camden series is only partially so, a portion belonging to the middle Tertiary or Claiborne and a still greater portion being of much younger age. At the base of this series Prof. Hill has also included as Tertiary some beds of cretaceous deposits. His Cleveland "red lands" are, according to Harris, of Claiborne and Jackson age.[68] It may also be stated that in some parts of Arkansas the Eocene is represented by a still lower phase than the Lignitic.

In Louisiana these beds are represented in the northwestern portion of the State. They have been described by Hilgard[69] and Hopkins[70] as the Mansfield group and recently by Dr. Otto Lerch as the Lignitic.[71] These beds are, in their main characteristics, similar to the lignitic of Texas and along the State line in Cass and Harrison Counties in Texas and Caddo Parish in Louisiana I have found them passing in unbroken continuity.

It would thus appear that the lignitic beds of East Texas can be directly connected with those of almost the whole of the Gulf States. A number of variations in structure undoubtedly occur between them and the corresponding beds of Alabama and Mississippi, where heavy beds of green sand, carrying numerous fossils form no inconsiderable portion of the series, and where the lignites are few and poorly developed. In Texas the lignites are very extensively represented by many beds of different thickness and make up a very fair proportion of the aggregate thickness of the lignitic stage and no trace of a single deposit of glauconite or green sand occurs anywhere. In fact, with the exception of petrified or silicified wood a few dicotyledonous leaves and stems of plants, all much broken, the entire series of the Texas Lignitic is wholly unfossiliferous.

If we follow Mr. Harris' division[72] and restrict the Alabama lignite to the first 600 feet of the beds considered by Smith and Johnson as belonging to that stage, we find constantly recurring changes from periods of low marshy coastal flats, during which the extensive beds of lignitic clays and shales and sands were laid down to periods in which the abundant fauna now buried in the glauconitic fossilifer-

[68] Geol. Survey of Ark., Vol. II of 1892, pp. 94–110.
[69] Am. J. of Sci., Vol. XLVIII, No. 144, Nov., 1869, p. 340.
[70] First Annual Report Geol. Survey of La., 1870, p. 83.
[71] Geol. and Agr. of North Louisiana. La. Exp. Sta. Bull., 1892, p. 9.
[72] Am. J. Sci., Vol. XLVII, April, 1894, p. 304.

ous green sands found suitable conditions of life. Although these changes were such as to build up very heavy deposits of each class, it would appear as if none of them continued long enough to enable the contained plant life to accumulate a sufficiently large growth to form anything beyond the merest trace of lignite.

During the whole of this period only some seven or eight seams of lignite have been laid down, and even these, with the exception of one, do not exceed two feet. In the first 200 feet, including the whole of the Hatchetigbee section and uppermost 30 feet of the Woods Bluff, no lignite occurs. Below this we have some 25 feet with thin beds. Of the 140 feet forming the Bells Landing stage only five feet of lignite are found, and these occur in three seams, the upper one of which is 2 feet thick and lies some 75 or 80 feet above the other two, which are only from 6 to 8 feet apart. The next lower or Nanafalia section shows 200 feet of gray sandy clays and cross bedded sand and glauconitic sands and clays with green sands containing *Gryphæa thirsæ*. About ten feet above the base, a bed of lignite from 4 to 7 feet thick occurs and this is the only lignite seen in that series.

Throughout the Texas areas the lignite beds everywhere form conspicuous objects in this horizon, although no attempts have yet been made to correlate them with each other.

These beds apparently represent a period when the whole coast was made up of swamps, lagoons and bayous, the extent of which will be best understood when we say that these deposits cover an area extending nearly 170 miles from north to south and 200 miles from east to west within the limits of East Texas alone. A rank vegetation grew on the marshy portions, and the rivers of the time having no fixed channels, distributed their waters through the lagoons and bayous, and into them and over the low islands carried their burdens of debris during periods of flood. With this debris came soft clay, sand, branches, limbs and trunks of trees, all of which went to swell the accumulations already gathering and aid in the formation of the lignites and associated beds of clay and sand. It is more than probable, however, that the lignites were largely formed from marine vegetation which grew where these deposits are now found. The Texas lignites are remarkably free from clay, and although trunks of trees, both in a lignitized and silicified form occur in them they are by no means numerous and are exceedingly few

when compared with the enormous amount of such wood found in the overlying sands.[73]

With the exception of a narrow strip of country lying to the west of a line drawn southward from the cretaceous border near Cooper, in Delta County, and passing a few miles to the west of Sulphur Springs, to the east of Emory, four miles east of Wells Point, between Mexia and Tehuacana and crossing the Brazos about a mile north of the Milam Falls County line, the lignitic deposits occupy the whole territory lying between the northern boundary of the Marine beds and the southern line of the Cretaceous. Along the eastern border of the State this area has a width of almost 160 miles but rapidly narrows in coming west. A line drawn across these beds through Tyler, Mineola and Sulphur Springs, to the cretaceous border on the Sabine, near the south side of Delta County, is only 75 miles and their exposure on the Brazos does not exceed 16 miles.

Along the western side, these beds rest upon the basal beds of the Texas Eocene, to the north they overlie and come in direct contact with the cretaceous marls and on the east, as already stated, they pass into Arkansas and Louisiana. To the south they are overlaid by the Marine beds and altogether cover an area equal to at least one-third of the whole Eocene tertiary in the State.

The dip of these beds appears to be gently towards the southeast, but the undulations referred to in the Marine beds also occur in the lignitic, making many instances of apparent return or northwesterly dips, and thereby making an effort to arrive at the actual thickness of the beds through the measurement of the dip difficult and of only doubtful accuracy. Fortunately, however, many deep borings have been made at various points and from these we are enabled to obtain a fairly accurate measurement of the thickness.

The topography of the country is simple. In the east the higher elevations are those points capped by the lower beds of the overlying Marine and which give the country a somewhat broken appearace. Near the centre and westward the country becomes of a more uniform level. It is mostly covered with heavy growths of pine and oak with mesquite bushes along the Brazos and through Robertson

[73] For connection between these beds and the Cretaceous see Science, Vol. XXII, No. 565, Dec. 1st, 1893, p. 300.

County. Prairie conditions prevail over some areas but only to an inconsiderable extent.

Basal Beds or Wills Point Clays.

These beds form the lowest deposits of Eocene age in Texas and rest directly upon the marls of the Cretaceous. They correspond in time with the Mathews Landing, Black Bluff and Midway sections of the Alabama lignitic and Harris' Midway stage of the lower Eocene.

In Texas these beds are represented by a series of yellowish brown, brown and bluish gray sands, yellow and blue laminated clays and massive clays containing numerous boulders of silicious limestone and two beds of white fossiliferous limestone. The yellowish brown sand contains numerous boulders of calcareous sandstones and limestone veined and streaked with calcite and enclosing occasional fossils and the sands themselves also carry a few broken shells. White, limy concretions and crystals of selenite are also numerous in some of the clays.

These beds have an aggregate thickness of about 260 feet and they occupy a narrow strip of country lying between the Lignitic on the east and the Cretaceous areas on the west. Their greatest width does not exceed some 13 miles in the vicinity of Wills Point and gradually narrowing to a point at each end. The greatest length from north to south does not exceed 170 miles.

The detailed information regarding these beds is meagre from the circumstances attending their condition and the time spent in making examinations. Their immediate contact with the overlying lignitic deposits has nowhere been seen. Near Wills Point the upper sands of the lower lignitic overlap for more than a mile and a half and on the Brazos the contact is obscured by wide spreading deposits of river alluvium and plistocene clays. The contact between the basal beds and the Cretaceous marls appears about four miles west of Elmo. In this region the dark blue laminated clays of the lowest Eocene rests upon the bluish weathering yellow marls of the Cretaceous Ponderosa beds. The section at this point shows:

1. Brownish gray sands containing boulders of limestone with thin seams of calcite and occasional broken shells . . . . . 25 feet.

2. Thinly laminated dark blue clays with broken bivalve shells in the upper division and occasional nodules of limestone . . . . . 30 "
3. Yellow Ponderosa marls forming the highest Cretaceous bed at this place . . . . . —

The contact between these beds and the underlying Cretaceous as seen in the Brazos river section presents a section of:

1. River alluvium . . . . . 4 feet.
2. Gravel . . . . . 1 foot.
3. Blue clay and sand breaking into nodules and conchoidal pieces, weathering into a grayish yellow and containing *Cucullaea macrodonta* Whitf., *Yoldia eborea* Conrad, *Venericardia alticosta* Con., var., *Calyptrophorus velatus* Con., *Cerithium* sp., *Crassatella* sp., *Apporhais gracilis* Ald., and *Ostrea pulaskensis* Harris[74] . . . . . 5 feet.
4. Transitional blue clay . . . . . 1 foot.
5. Massive blue clay with Baculites and other Cretaceous fossils . . . . . 14 feet.

About 90 feet above the base as seen at Elmo in Kaufman county there are two beds of limestone, the upper one measuring eight feet and the lower ten feet in thickness. These are separated by two feet of brown sand. These limestones are highly fossiliferous containing such fossils as *Cucullaea macrodonta* Whitf., *Venericardia alticosta* Con., var., *Venericardia planicosta* Lam., *Crassatella* (Midway sp.,) *Cytherea* sp., *Pyrula* (*Fusoficula*) var. *Pseudoliva unicarinata* Ald., *Pleurotoma* (*Pleurotomella*) *anacona* Harris, n. sp., *Ostrea pulaskensis* Harris and *Turritella* sp.

These two beds are seen about a mile north of Elmo in the following section:

1. White fossiliferous limestone . . . . . 8 feet.
2. Brown sand . . . . . 2 "
3. Limestone same as No. 1 . . . . . 10 "
4. Dark bluish gray sand . . . . . 30 "

At Rocky Cedar only the upper bed is seen and is here 20 feet thick.

[74] Harris MSS.

Whether these limestones form a connected bed throughout the whole length of the area is not known. They occur about twelve miles further south at Kemp where they contain *Cucullæa macrodonta* Whitf., *Cytherea* sp., *Turritella alabamensis* var. *prealaba* Con., and *Mesalia alabamensis* Whitf.[75]

In the vicinity of Tehuacana, Limestone county, these limestone beds again make their appearance with an increased thickness. Here the beds form the surface over considerable areas and are underlaid by a brownish gray sand presenting the following section:

1.	Whitish to grayish white limestone containing *Ostrea alabamensis* Lea., *Volutilithes* sp., *Venericardia planicosta* Lam., *Cytherea* sp., *Mesalia alabamensis* var. *medria* n. v. Harris, *Turritella multilira* Whitf., and *T. alabamensis* var.	40 feet.
2.	Brownish gray sand changing to a brown near base	—
3.	Black shaly clay (Cretaceous)	—

These limestones are again seen at Hornhill in the same county where they carry practically the same fauna and the Brazos section is seen in the following:

(a.) Section at Oyster Bluff (Penrose), Two Miles Above Mouth of Pond Creek:—

1.	River alluvium	4 feet.
2.	Conglomerate	2 "
3.	Coarse conglomerate with boulders	1½ to 2 "
4.	Thinly stratified yellowish gray clay, sand and blue clay with occasional rounded boulders of calcareous sandstone	10 "
5.	Blue laminated clay, fossiliferous	4 "
6.	Thin bed of nodules and hard fossiliferous limestone	1 foot.
7.	Thinly laminated gray clay and sand	3 feet.
8.	Bluish gray sand	1 foot.
9.	Thinly laminated dark blue clay and sand . .	3 feet.
10.	Dark blue laminated and fossiliferous sand . .	2 "

The fauna belonging to this section comprise *Ostrea præcompressiros-*

[75] Harris MSS.

tra Har., *Cytherea*, *Natica*, *Cerithium whitfieldi* Heilprin, *Pseudoliva ostrarupis* Harris, n. sp. *P. ostrarupis* Harris, n. var., *Fusus ostrarupis*, Harris, n. sp., *Pleurotoma* (*Pleurotomella*) *anaeona* Harris n. sp., *Pl.* (*Surcula*) *ostrarupis* Harris n. sp., *Cerithium penrosei* Harris, n. sp., *Tellina* (*Leda*) *milamensis* Harris large variety, n. sp., and *Leda milamensis* Harris.[76] These fossils occur almost altogether in the beds of blue clay.

The section shown at this place is probably the uppermost beds belonging to the Basal clays and No. 4 may represent a transition bed between these and the overlying lignitic, as it partakes of some of the character of both stages. The nearest known lignitic beds in the river section are at the mouth of Pond Creek, two miles below, but occur away from the river on both sides much nearer than this, although no actual contact can be seen :

(b.) Section on C. Cribbs League, Between Two and Three Miles Above (a.) :—

1.	Brown sand and gravel	2 feet.
2.	Yellow clay	4 "
3.	Ledge of silicious limestone, fossiliferous . .	2 "
4.	Yellow clay same as No. 2	5 "
5.	Limestone same as No. 3	2 "
6.	Dark blue laminated clay showing lines of lamination on weathering.	30 to 35 "

The fossils obtained from this locality embrace *Cucullæa macrodonta* Whitf., *Yoldia eborea* Conrad, *Volutilithes rugata* Conrad, *Venericardia alticosta* var. Conrad, *Calyptrophorus velatus* Conrad, *Nucula magnifica* Conrad, *Crassatella kennedyi* Harris, n. sp., *Fusus ostrarupis* Harris, n. sp., *Dentalium* sp., *Turritella mortoni* Conrad, var., *Ostrea pulaskensis* Harris, and *Lucina*.[77] These fossils mostly occur in the limestone ledges which here, although much altered in texture and appearance, evidently represent the two beds found at Elmo and on Rocky Cedar. The limestones here and at the next section above are soft and easily broken, of a brownish gray appearance on the outside but are grayish blue in the interior. They have a tendency to break up and assume a nodular form.

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[76] Harris MSS.

[77] Harris MSS.

Half a mile below the contact of the Cretaceous and at the foot of Blue Shoals we have another section :

(c.) Section at foot of Blue Shoals Half a Mile Below Tertiary—Cretaceous Contact on Brazos River :—

1.	Brown sand river alluvium	10 feet.
2.	Blue indurated clay with boulders of limestone containing *Ostrea pulaskensis* Harris, and other fossils	5 "
3.	Laminated blue almost black fossiliferous clay with thin seam of indurated clay on top . .	4 "+

The fossils obtained here with the addition of *Turritella alabamensis* Whitf., *Pecten alabamensis* Aldr., and a species of *Cerithium* are the same as those occurring in (b.) a few miles down the river and most of them occur at the Tertiary–Cretaceous contact half a mile farther up. These have already been shown.

These beds as shown in the river section undulate to such a degree that many of them dip sharply and pass beneath the river level only to rise again in some small exposures farther down. These undulations are not uniform in their length as the usual condition appears to be a long gentle slope, succeeded by a sharply abrupt descent which is represented in a much slower rise where the same beds appear again. On this account we have two different rates of dip towards the southeast with one towards the northwest, although the whole series has a gentle slope or lowering towards the southeast; That is, the farther we go up the river the longer and higher the folds become.

These beds have been traced westward in Falls and Milam counties for some distance by Messrs. Taff and Stone of the Texas Geological Survey. They do not, however, appear to occur anywhere along the Cretaceous border east of Hopkins county. At least they are not known in that region nor do they appear to be known anywhere east as far as Rockport near Malvern and near Alexander Station on the St. Louis and Iron Mountain Railroad in Arkansas, where a small outcrop of the limestone belonging to them appears carrying *Ostrea pulaskensis* Harris, and some other fossils of the same age.

Whether these beds ever formed a continuous belt along the cretaceous border through this region and that this belt has long

since been eroded and carried off, or whether they are covered up by the overlapping of the later beds we have as yet no evidence to offer, but if they occupy the same relative position here as in the west, then the presumption is that they never existed and that they occupy a very minor position in the Tertiary scale and were only laid down in isolated positions, and, while differing materially from the great body of the lignitic, should be considered as the equivalent in time at least, to a portion of the basal deposits of that stage. No lignites occur in them and they appear to be at least partly of marine origin.

Mr. Harris has classed the Matthews Landing marls, Black Bluff clays and Midway clay and Limestone of the Alabama Lignitic under the single title of "Midway." In this the Texas Survey has followed Mr. Harris and whether the Texas beds will admit of the threefold division made in Alabama, or, if so, where the lines of separation are to be drawn our present information will not allow a definite settlement of the question. As it appears at present these beds can be correlated only with the last two, Black Bluff and Midway. The clays and limestones with their contained fossils as found on the Brazos and in the neighborhood of Elmo and Wills Point correspond closely to these divisions but whether the gray sands and sandy clays with their boulders of calcareous sandstones can be correlated with the Mathews Landing, the proof is at present deficient.

These beds, unlike the lignitic, cannot be traced continuously across the intervening States. They are not continuous in Texas and only appear as isolated deposits of generally small extent in Arkansas, and Smith seems to think the "Flatwood" in Mississippi belong to the same age.

The country occupied by the Basal beds in Texas is generally undulating, and prairie-like conditions prevail throughout the northern portion. Towards the south the prairies are broken by growths of dwarf mesquite which is fast covering the whole area.

Résumé of History.

The close of the Cretaceous in the East Texas region found the physiographic conditions of the coast line much the same as we find them along the present shore. The coastal plain comprised a series of clays in places, giving place to sands in others. Nowhere were any of the harder limestones of the upper cretaceous seen. This

cretaceous shore line undoubtedly stood at a slightly higher elevation and extended many miles to the southward of where we now find its outcroppings. The "islands" or isolated patches of beds belonging to that age, found in the salines of Smith, Vanzandt and Anderson Counties then formed an integral portion of the uppermost cretaceous beds. In front of this line and extending from 75 to 100 miles still farther south and seaward, there was a subcoastal plain or submerged plateau lying at no great depth below the waters of the gulf and probably more or less subject to exposure at low tide.

With the exception of the Brazos and Trinity Rivers no large streams broke the coast line but numerous smaller water courses, corresponding to such streams as the Angelina, Nelus, San Jacinto and others, in times of freshets, poured their torrents of muddy debris-laden waters into the shallow sea, covered the subcoastal plain with a varied assortment of sand, mud, leaves, branches and trunks of trees and quantities of other vegetation and probably animal remains, and in periods of dry weather dwindled down to shallow pools and sluggish bayous in which their waters scarcely moved.

Although the land stood higher than at present this was essentially a period of subsidence and denudation. So far as we can see, the currents must have set in from the southwest and the waters along the western side of the tertiary areas were deeper and stronger than those along the northern coast. A deep channel from 15 to 20 miles wide appears to have been excavated along the eastern cretaceous shore, cutting off the cretaceous islands now found, and in place of the deposits removed, left behind the 260 feet of laminated clays, sands and limestones now known as the "Wills Point" or "Basal Beds."

The presence of this channel and the subsequent deposition of these basal beds is indicated by the existence of the same character of deposit showing a return, or northwestern dip at several points along the eastern side of the channel. This is clearly shown at Grand Saline, in Kaufman and in Anderson County.

The materials forming the new deposits were largely derived from the destruction of the old. This is shown in the chemical composition of the two[78] and besides the new or basal Eocene sands contain many rounded boulders of limestone containing cretaceous fossils.

[78] Science, Vol. XXII, No. 565, Dec. 1st., 1893, pp. 297–300.

The sea then had free access to this portion of the shore, at least, and the clear marine water meeting the mud-laden fresh water of creeks and rivers caused the latter to drop their burdens with the result of a deposition of a great depth of laminated clays and sands,[79] Marine and fresh, or brackish water conditions alternately prevailed. The subsidence continued and the marine conditions becoming stronger many of the marine forms of life gradually crept up along the shore and we have a solid eight feet of limestone. A slight change takes place and two feet of sand are laid down, again to be succeeded by another bed of limestone of the same character as before, this time ten feet in thickness.

Following this upper limestone we have 120 feet of clay and finally 30 feet of sand with calcareous boulders and a few fossils and then another change takes place. The old channel with its sands, clays and limestones is completely obliterated and a shallow, brackish water condition of affairs takes place, covering the whole area from west to east with a totally different set of deposits. These form the great lignitic series of this region.

The changes that ushered in the lignitic stage brought about the final destruction of the glauconitic sandy portion of the upper cretaceous, completed the isolation of the cretaceous islands and laid down great beds of sand along the whole coast. Owing to extensive overlapping of the newer members of the series, the base of these beds is seldom seen but wherever sufficiently deep exposures occur the basal portion of these lignitic deposits are found to be made up of coarse bluish-gray, to gray, sand with occasional interstratified strata of indurated sand or soft sandstone, more or less calcareous, and at wide intervals these deposits are interstratified with thin strata of laminated clay. In the Brazos River section these deposits have a thickness of about 300 feet, but they become thinner as they extend eastward and westward from this line. In the northeastern portion of the State these sands rest directly upon the cretaceous and are very much thinner and have a thickness of probably not more than 50 feet.

The conditions brought about by these changes appear to have been inimical to animal life, or at least to the preservation of its remains. Nowhere within the whole region has a solitary individual

[79] Geikie's Text Book of Geology, Second edition, p. 355.

fossil been found and even the lignite so plentiful in the upper clayey portion of the lignitic appears to be wanting altogether or is extremely scarce. From this condition we might infer that the coast line was for a long time faced by a broad expanse of littoral sands, over which the sea flowed intermittently and at irregular periods, and at different depths, carrying with its waves enormous, although irregular quantities of sand. The fresh water streams, with the exception of the two rivers, the Brazos and Trinity, having no fixed channels spread their deposits over the sands to be afterwards re-arranged by the succeeding tidal waters.

The marine action being intermittent the sandy shores would necessarily be exposed to atmospheric agencies for frequent and probably considerable periods of time, while the fresh water deposits would be thin and widely spread, and disturbed if not altogether destroyed, by every inundation of the sea. Under these conditions the irregular thickness of the beds and their indurated portions may readily be accounted for while at the same time they would be extremely inhospitable for mollusean life and any stray shell that might find its way into the region would suffer desiccation and be almost immediately broken to a fine powder. Many of the bays along the southern coast of Scotland present the same features at the present day. There we have a series of deposits of sands and clays forming the immediate shore line elevated from 7 to 10 feet above a broad foreshore of sand, over which the sea only flows at periods of extreme high water or during storms. Immediately in front of this, to the seaward, lies a belt of sand covered but lightly during "spring" tides and dry during the periods of "neap" or low tides, while again in front of this, we find the life zone or region of mollusks. This is covered by every tide that flows. The higher grounds are under cultivation and the fore shore is covered with a scanty vegetation of samphire and other salt-loving plants. This strip forms the well-known "links" of that coast. The two outer zones are totally devoid of vegetation. The same condition of affairs also prevails at the head of the Bay of Fundy, in Nova Scotia and throughout many other portions of this continent.

The fauna of this period must be looked for much farther to the south and southwest where marine conditions prevailed altogether, and when the sea was gradually raising up a barrier of sand between itself and the shore. This barrier, by closing out the sea, or

the greater portion of its water and at the same time damming back the rivers allowed the fresh water to gradually spread over the whole area and form a fresh water lagoon into which the rivers and streams in time of floods carried great quantities of mud and fine sand. The deposition of these in the still waters of the lagoons gradually formed the sandy clays found sparingly distributed among the sandy deposits. But as the whole work of the sea is an incessant building up and tearing down, a period of storms or extra high water would eventually destroy the sandy barriers and again the whole flat would be subject to marine influences and the deposition of marine deposits. Probably the rivers themselves, by the washing out of the bars at their mouths aided in the work.

Although the land had gradually subsided, the subsidence scarcely kept pace with the upbuilding of the sea and each succeeding inroad would have less influence than the preceding, until a time would be reached when the rivers and streams gained the ascendancy and then would commence a time of heavier and more extensive clayey deposits. Most of these clayey deposits are laminated and from this we may infer that they were never absolutely beyond marine influence, however weak it may have been at times.

At that time, we may reasonably suppose, the sea had formed a broad bar of sufficient strength to prevent the ingress of salt water except on very exceptional occasions or at low points in much the same manner as along the present coast. No doubt there were some differences but these we are unable to point out as all evidences have long since been covered up by overlying deposits or erosion.

It was to this time we may ascribe the beginning of the deposition of the vast beds of lignite so prominent throughout the greater portion of the area. Prior to this no lignite appears to have been formed and none have been found in the lower sands. It must be remembered that throughout the whole lignite field the lignites rest upon clays and that these clays contain great quantities of carbonaceous matter in the forms of leaves and stems of delicate plants, none of which could bear transportation to any great distance.

Many conditions of origin have been ascribed to these lignitic deposits. Some writers assert "that these beds were formed as off-shore deposits and the beds of lignite are accumulations of land vegetation carried out to sea and becoming water-logged, sunk in heaps in much the same manner as beds are forming in the bed of the present

gulf."[80] Others, again, ascribe to the lignites a swamp or lagoon formation and favor the theory that the greater portion of the necessary vegetation grew where the lignite is now found. Dr. Penrose attributes their origin in Texas to bayous and lagoons on the coast and says: "Such places were probably heavily timbered and year after year the trees dropped their leaves and dead branches on the moist ground. Here they collected and were mixed with dead reeds, moss, grass, etc. As the trees themselves died, they also lay down in the same grave and rotted in the same boggy waters as their leaves and branches, until often a great thickness of decayed vegetable matter had been collected."[81] Another theory might be added. These lignite beds grew upon the exact spots in which they are now found and are due to the swampy condition of the region, but the material contributing to their structure did not consist of large trees but rather of the growth of small marsh plants such as are found in the underlying clays, that the presence of tree trunks in these beds is largely adventitious and brought in during periods of inundation. When the plant growth became strong enough to support arboreal vegetation small trees undoubtedly did grow in some portions of the lagoon but never to such an extent that they could contribute much toward the formation of the great lignite deposits as we now find them.

To the first of these theories, that the beds of lignite are due to accumulations of land vegetation carried out to sea, there are many and serious objections. In the first place, we have the wide, almost universal distribution of these lignite beds, their great thickness in many places, their exact superposition one above the other for at least six times, their general purity and the utter absence of fossils. Passing over the question of the enormous amount of vegetation necessary to be carried out to sea to form these beds we are confounded with the question of their superposition. In order to obtain this we have to suppose a series of undulations of uniform elevation and subsidence with a uniform series of currents having equal powers of transportation, extending through an enormous length of time. It will also be necessary to suppose long periods of cessation in the deposition of vegetable matter and during which great thick-

[80] Geol. Survey of Ark., Vol. II, of 1888, p. 60.
[81] Geol. Survey of Texas, First Annual Report, 1889, p. 94.

ness of sands and clays were laid down. Another point not satisfactorily explained by this theory is the general homogeneity of structure exhibited by these beds and their freedom from interlaminations of or interstitial clays. Vegetable deposits due to drift material would naturally contain more or less clay intermixed with the deposit. And again we can hardly suppose the sea to have been devoid of either vegetable or animal life.

The theory that these lignite beds were formed from materials growing *in situ* while probably it does not explain all the difficulties attached to the question comes much nearer doing so than any other. As far back as 1828 A. Brongniart held the opinion that coal was formed of plants growing *in situ* and in 1853 Le Conte taught that coal was formed as in the peat swamps of the present day, but these swamps occurred at the mouths of large rivers and were subject to overflows by the rivers and occasional inundations by the sea.[82] The absence of river mud he ascribes to a straining operation of the plants along the margins of the swamp and quotes Mr. Lyell as the authority for the statement that "although the peat swamps of the Mississippi are annually flooded by river water they are entirely untouched by river mud. These favored spots are surrounded, partially on the side next the river, by dense vegetation, which, acting as a sieve, completely strains the water of its mud before it reaches the peat swamp. The water of these swamps is, therefore, pure, and pure peat has been quietly depositing there for ages.

According to Gümbel coal should be considered an inland deposit formed in wide, flat depressions of continents and also on low grounds along the sea coast. Undisturbed growth of marsh vegetation alternated with floods during a long continued subsidence might reach locally a thickness of several thousand yards of successive beds of coal, sandstone and shale.[83]

As already suggested the sea had reached to a considerable distance south of the lignitic areas and a broad but low sand bar, broken in places, protected the sandy plains from marine invasion. Erosion had begun work on this sandy waste and the different streams were being gathered into the courses they were subsequently to occupy. This cause of destruction operated rapidly, as it does now,

[82] Smithsonian Institution Report of 1853, pp. 136-137.
[83] Beiträge zur Kenntniss der Texturverhält d. Mineralkohlen, 1883.

and in a comparatively short period the chief drainage outlets such as the Sabine, Sulphur, Neches and the other smaller rivers had outlined their main channels and drainage areas. The Brazos and Trinity rivers being already formed, enlarged their scope of operations, and here, we have also to consider the influences of the Red River and Mississippi drainage systems on the coast. Fresh water gradually spread over the greater portion of the regions and by the deposition of the loads of mud brought down by the different streams covered the flat, sandy country with a soft clayey soil. Irregularities of deposition, accentuated by the irregularities of erosion and the eternally changing conditions of the sand bars in the rivers and the periodical flooding and low water changes in the rivers led to the formation of irregular ridges of sand and the lenticular deposits of clay we now find throughout the whole area.

The damming of broad valleys of erosion by the sand bars at their mouths formed wide tracts of marshy lands or lagoons and these gradually acquiring a vegetation fitted for such localities became the birth places of our extensive lignite beds.

This condition went on year after year, periodical floods brought into the marshes additional supplies of fresh water. There is no reason to suppose there was a greater absence of the straining influences of the plants along the outer edges then, than now, and every one can see this operation being carried on in marshy regions at the present day. The presence of small trees occasionally found in the lignite beds may be accounted for by the fact that during the course of time these marshes acquired a suface soil of sufficient density to support a growth of such swamp loving trees as cypress, gum, etc. These grew, flourished and eventually dying, their trunks fell and were buried in the soft vegetation of the marsh. Some of them appear to have left their stumps standing where they grew.

During the course of time in which these marshes and swamps were growing it is reasonable to suppose that many of the uplands and ridges between them acquired a vegetation. Marshy plants and bushes fringed the pools and shed their leaves and branches into them. Stronger trees grew on the higher grounds and the whole country presented a forest clad appearance. Such a condition is seen to-day along many of the rivers. Sloughs, ponds and "cut offs" are common along the Sulphur and other streams in the northeastern portions.

This vast growth of vegetation implies several conditions of existence. The climate must have been moderately warm, very moist and the whole surface of the land slowly subsiding. The whole territory lay at a very small elevation above the sea and but a slight oscillation of the land was necessary to place the whole again within the grasp of the sea.

How many times these conditions were repeated we do not know. That would depend upon the number of lignite beds, but as these have not been correlated with each other, if indeed they ever can be, over any more than small areas, even these cannot be taken absolutely as a chronometer reliable enough to indicate the number of oscillations that may have taken place.

Towards the close of this stage there came a time, however, in which the sea began to assert its right of domain and to again cover the face of the country with sand and sandy clay. This time is represented in the beautifully striped or banded beds of the Queen City deposits. The time of lignite making had come to an end and a new order of things commenced. These beds represent a period of comparative quiescence, and from the uniform thickness of the lamination and alternate banding of red and white sands and clays, appear to have been a beach formation. How far these beds covered the lignites is not known; they are only found as remnants of what probably was a very widely extended series of deposits. Their northern boundary shows signs of extensive erosion and their southern margin has never been seen.

The relative time of deposition of these beds could not have been very long as the greatest thickness found anywhere does not exceed 65 feet. They probably represent a period in which the land lay very low and open to a long sweep of tidal waters.

A slight change in the relative positions of land and sea again brought deeper water along the Texan coast and heavy beds of sand were heaped up and spread along the shore. A few of the marine forms of life began to appear. Among them we find some such as *Venericardia planicosta*, *Turritella* sp., and which had survived the changes from the basal beds up. This condition continued until nearly 300 feet of sands and sandy clays had been deposited. The faunal life increased somewhat during that time but did not, so far as our evidence shows, reach the quantity of richness of the latter half of this period.

About this time a change due to some extraneous causes occurred. Whatever the cause of this change may have been it induced a flexing, or gentle undulation, involving the whole series from the middle of the Marine beds backward to and including a portion of the upper Cretaceous. This flexing apparently brought the long period of subsidence to an end. The whole of the lower Marine beds were brought to the surface and a period of elevation began. During this stage the last 250 feet of the Marine beds were deposited in comparatively shallow water and along a sandy floor sloping gently seaward.

With the close of the Marine beds the elevation ceased, and for a long period the land remained stationary. During that time erosion was working actively. The sea to the southward was cutting the sloping shores and carving them in many places into steep cliffs; the rivers were widening and deepening their channels, carrying their burdens of debris seaward and depositing them in the shallow waters of the Gulf. Here these materials were sorted and arranged into banks of sand with muddy intervals, gradually filling up the shallow shore waters. Again we find the marine waters being gradually closed out, the streams gathered into sluggish bayous and the whole drainage system disarranged. Fresh and salt waters met and mingled in the bayous and occasional inundations covered the whole region. Marsh plants, grasses, reeds and palmettos gradually overspread the wide domain now occupied by the Yegua clays. Again we have a period of slow subsidence and a return to very similar conditions of life as those of lignitic times. The bayous were probably wider, deeper and clearer than those of the lignitic stage and life appears to have been more plentiful. The alligator lived in the marshes and marine shells such as *Tellina mooreana* Gb. *Turritella nasuta* var. *houstonia* Harris, *Natica recurva* Ald., and *Nucula magnifica* Con., found a means of surviving in some of the sandy deposits along the lines of the greater water courses.

The time of depression continued long enough to deposit extensive beds of lignite clays and sands to a total thickness of 1,000 feet.

If we might suppose a slight uplifting of the land areas to the north and consequent tilting of these beds towards the sea we would then find a considerable portion of these marshy areas submerged by deeper and clearer water, a deposition of sands and clays going on and a partial return to marine conditions of life. The newer

deposits would be somewhat unconformable to the lower and submerged ones and would have an appreciable quantity of shore debris mixed with the cleaner marine sands.

This is the condition in which we find the lower deposits of the Fayette sands. These beds are irregular in form, wedge-shaped, cross-bedded and often lenticular, the whole indicating a deposition in very shallow water subject to a strong sweep of the tide and often affected by storms. The life of the time as represented in these beds shows leaves, stems and trunks of trees belonging to low-lying, marshy lands. Palm wood is plentiful while the stems and leaves of the palmetto, rushes and marsh grass may be found in some localities in abundance, showing that when these beds were being deposited the marshy tracts of the Yegua clays to the northward were still the home of such growths. None of these are indigenous to the Fayette sands and exist there only in the form of drift material cast up by the sea. Near the top of the Fayette sands we find trunks and limbs of trees of large size, many of them even now showing diametric measurements of over three feet, and although some show a length of 25 or 30 feet the greater portion of the logs do not exceed ten or twelve feet in length. Occasionally a stump with the larger roots attached may be found, but this exceedingly rare. A peculiarity regarding these trees is that they are every one in the form of wood opal or in an opalized condition, vitreous and clear when broken, breaking with sharp cutting edges and retaining every mark and line of growth as it appeared in the tree. The outside of these woods is generally a dull white showing a process of decay. This form of wood is peculiar to the Fayette sands and occurs nowhere else within the Texan regions.

The faunal life connects these beds with the whole series of the Eocene stages as shown in the Texan section and is decidedly marine in every phase. *Venericardia planicosta* Lam., *Calyptrophorus velatus* Con., *Mactra* sp., *Dentalium minutistriatum* Gabb, var. *dumblei* Harris and *Corbula alabamensis* Lea, as well as many others represent the inhabitants of this portion of the sea at that time.

To the southward the land was sinking and the sea creeping farther up over the Fayette shores. A deposit of clay was being laid down which within a short time was destined to become the last representative of Eocene times in this portion of the world. These

were the Frio clays. With the deposition of these clays the Eocene of Texas came to an end.

Towards the close of the Fayette time there began a series of earth movements the initial causes, or full effects of which, cannot be indicated or understood by what we may observe within the East Texas areas. Only a few of the results, and these are small, may be seen there. Hot springs with an abundance of silica in solution appear to have formed a predominant feature and silicious sinters form extensive deposits through several counties occupied by beds of Fayette time. To these solutions of silica we may possibly ascribe the transformation of the fossil wood into the condition it is now found as well as the many deposits of quartzite found in the same portions of the State.

These earth movements and the deposition of the sinter continued through the deposition of the Frio clays with which many of the deposits are interstratified and while we need not discuss the causes of these movements here it may be said that the ultimate effect was, at least in Texas, to elevate the whole of the Eocene beds into dry land and this condition continued far into Miocene times.